PERCEIVED IMPACT OF VIRTUAL SCENARIO-BASED BRANCHING SIMULATIONS AMONG RADIOLOGY PROGRAM STUDENTS

by

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The following individuals read and discussed the dissertation submitted by student Kimberly Lynn Onstott, and they evaluated her presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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DEDICATION

This dissertation is dedicated to my best friend and biggest supporter, my husband Brent, who has always encouraged me to pursue my dreams. I would also like to dedicate this dissertation in memory of our dear friend David R. Eby, Colonel U.S.A.F., who not only taught me to fly, but whose generous spirit and faith in me gave me the strength to continue to soar.

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ABSTRACT

The influx of medical technology and medical knowledge creates challenges for healthcare providers in maintaining up to date knowledge and skills for their practice. Healthcare educators are further challenged in that the goal is to encourage learners to become competent healthcare providers who are knowledgeable and skilled, self-directed, and who will think critically and ethically when faced with challenging situations. Advancing imaging technologies and new complex procedures in radiology increase the risk of harm for patients and providers as advanced imaging is often learned outside of a primary degree in radiology with real patients through on the job training. Online education has been a way for the profession to extend needed education to working technologists, however, radiology education programs need ways to improve the level of learning in online advanced modality courses. This study explored an innovative teaching method to identify which will aid in current and future demands in radiology. Based on a review of the literature on scenarios, simulations, and virtual learning environments, virtual scenario-based branching simulations were designed, built, and implemented for this study. The virtual 2D role-playing scenario in which the student played the role of a new technologist in an advanced imaging suite provided students an opportunity for experiential learning online. The branching design, in which the patient and storyline evolves with the learner's decisions required the learner to think critically and draw upon previous knowledge to make decisions about what should be done. This changed the direction of the stories and the outcomes of the virtual patients and

personnel. The simulations were designed to enhance the level of learning in magnetic resonance imaging and in computed tomography online courses. They were tested with 57 advanced modality students to determine the impact the virtual scenario-based branching design had on student satisfaction with the experience and also their perceived confidence in making critical decisions in real practice.

This mixed methods case study provided an analysis of both quantitative and rich qualitative data in a concurrent design. The participant voice provided insight into how this experience positively impacted this particular group of students and it also provided support for further development of virtual scenario-based simulations in a healthcare context.

The implications for these simulations are wide-ranging. From the results of this study, this innovation appeared to provide a level of learning that emulated a clinical rotation. As the education of healthcare professionals requires deliberate practice of technical and cognitive skills, these simulations do not aim to replace hands-on learning with actual patients, but they do aim to improve student satisfaction in learning and to enhance the perceived confidence in transferring their knowledge to enhance actual practice, thereby minimizing risk to patients.

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LIST OF ABBREVIATIONS

3DCG	3-Dimensional Computer Graphics models
ACICBL	Advisory Committee on Interdisciplinary, Community-based Linkages
ACR	American College of Radiology
ARRT	American Registry of Radiologic Technologists
ASAHP	Association of Schools of Allied Health Professions
ASRT	American Society of Radiologic Technologists
AVM	arteriovenous malformation
BIg PHARMA	Background, IV, Pregnancy, HPI, Age, Renal function, Medications, Allergies
BSU	Boise State University
CAQDAS	Computer Assisted Qualitative Data Analysis Software
CIN	Contrast-Induced Nephrotoxicity
CPR	Cardiopulmonary Resuscitation
CQR	Continuing Qualifications Requirements
CT	Computed Tomography
CTA	Computed Tomography Angiography
DNP	Doctor of Nursing Practice
DP	Deliberate Practice
E-learning	Electronic Learning

EDH	Epidural Hematoma
EVE	Educational Virtual Environments
GBS	Goal-Based Scenario
GC	Graduate College
GFR	Glomerular Filtration Rate
HIPAA	Health Insurance Portability and Accountability Act of 1996
ICH	Intracerebral Hemorrhage
IOM	Institute of Medicine
IQR	Interquartile Range
LMS	Learning Management System
Mdn	Median
MAI	Metacognitive Assessment Inventory
MMORGS	Massively Multiplayer Online Games
MRI	Magnetic Resonance Imaging
MS	Multiple Sclerosis
MSU	Midwestern State University
MUVES	3D Multi-User Virtual Environments
n	Sample size
N	Population size
NLN	National League of Nursing
OECD	Organisation for Economic Co-operation and Development
PBL	Problem-based Learning
PE	Pulmonary Embolism

PET	Positron Emission Technology
PET-CT	Positron Emission Technology Computed Tomography
PET-MR	Positron Emission Technology Magnetic Resonance Imaging
RF burn	Radiofrequency burn
SAH	Subarachnoid Hemorrhage
SAMPLE	Symptoms, Alert & oriented, Mental state, Physical needs, Language barriers, Events leading to exam
SAR	Specific Absorption Rate
SDH	Subdural Hematoma
SHOP BAIT	Screening *2, HPI, Order, Priors, Bloodwork, Assessment, Implanted devices, Thermoregulatory disorders
SPSS	Statistical Package for the Social Sciences
t	t-test value
TDC	Thesis and Dissertation Coordinator
TES	Technology-Enhanced Simulation
VP	Virtual Patient
WGCTA	Watson-Glaser Critical Thinking Appraisal
WWI	World War I

CHAPTER ONE: INTRODUCTION

Harm from medical error has been a topic of concern since the Institute of Medicine (IOM) published a study in the late 20th century that revealed an alarming number of medical errors that led to patient death or harm, such as wrong-site errors, communication errors, medication errors, and more (Lark, Kirkpatrick, & Chung, 2018). In an effort to increase patient safety, educators in the field of radiologic sciences have a responsibility to disseminate knowledge in a manner that will produce competent healthcare providers who are knowledgeable and skilled, self-directed, and who will think critically and ethically when faced with challenging situations. Although awareness has increased, medical errors continue to plague the healthcare system (Makary & Daniel, 2016). Advancing imaging technologies and new complex procedures increase the risk of harm for patients and providers in radiology. As a way to mitigate risk, regulating bodies and professional organizations have recommended healthcare educators explore more effective and innovative teaching strategies (ACICBL, 2011; IOM, 1999; IOM, 2003; Martino & Odle, 2008).

Background

Since its inception into clinical use in 1896, radiologic sciences and radiologic education have evolved along with advances in imaging technology and advances in the medical field (American Society of Radiologic Technologists [ASRT], n.d.). By definition, radiologic sciences is the branch of medical science that studies the use of electromagnetic radiation or radioactive material that produces diagnostic images of anatomic structures or aides in the treatment of disease (radiology, n.d.). The radiation producing X-ray and fluoroscopic technology revolutionized the way medicine was first practiced and has continued to be a significant part of the health care regimen ever since (Spiegel, 1995).

Radiologic Science Education

Education programs for radiographers began in the early 1900s. Marie Curie, Physicist, developed the first known radiology program during WWI (Curie, 1937). She recognized early on in the war the applicability of this new technology for wounded soldiers, and, in an effort to bring this technology to the battlefields, she invented the mobile x-ray car. Twenty cars were built with x-ray units and photographic darkroom equipment installed. Curie thus developed a curriculum to train 150 women to operate these units. Curie's program included aspects of anatomy, patient care, electronics, and the use of radiation-producing equipment. Since then, radiology education programs in the United States, guided by the national credentialing agency, the American Registry of Radiologic Technologists (ARRT), have expanded knowledge requirements as the field has grown. Radiographers are primarily educated in the field of diagnostic radiology, which includes, but is not limited to an intense focus on patient interactions and management, radiation physics and radiobiology, radiation protection, image acquisition and technical evaluation, equipment operation and quality assurance, procedures for positioning, anatomy, procedure adaptation, and evaluation of displayed anatomical structures (The American Registry of Radiologic Technologists [ARRT], 2016). Program designs characteristically include passive lecture-based on-campus courses combined with on-campus laboratory practice. The didactic courses are followed by, or are combined with, an extensive clinical practicum at a hospital, clinic, or imaging center in which the student practices outside of the university on real patients to engage their experiential learning (Trad & Larrotta, 2016). This method of teaching continues to be commonplace for many radiology programs (Kowalczyk, 2011).

Radiologic Sciences Profession (Radiographer)

Radiographers are medical practitioners formally trained in radiologic sciences. Radiographers are experts in their field as they receive more education and training than radiologic technicians do. They are credentialed in the United States through the national credentialing agency, the ARRT. The requirements for this registry include completing an associate’s degree or higher, completing an ARRT-approved educational program, successfully demonstrating clinical procedures, and successfully scoring a 75% or better on the ARRT national registry examination (ARRT, 2016). Once registered, radiographers are required to maintain proficiency through biennial continuing education, and, if any credential was earned after Jan.1, 2011, they must complete a re-evaluation of their skills with the ARRT's decennial Continuing Qualifications Requirements (CQR) (ARRT, 2017).

Radiographers are also considered a part of a larger group of healthcare professionals called allied health professionals. The Association of Schools of Allied Health Professions (ASAHP) defines allied health professionals as the segment of the workforce that delivers services involving the identification, evaluation and prevention of diseases and disorders (The Association of Schools of Allied Health Professions [ASAHP], 2015). These professionals consist of over 60% of the healthcare team and include non-nurse, non-physician health care providers, such as audiologists, respiratory therapists, physical therapists, radiographers in many different areas of radiology, and many other healthcare providers and support personnel (ASAHP, 2015).

With advances in imaging technology and procedures, combined with the rapid growth in medical knowledge, the role of the radiographer in the professional environment now expands beyond the competencies learned in the primary discipline. The radiographer, or imaging professional, is a patient care provider, a technology expert, and a procedural expert requiring much higher levels of thinking processes (Pieterse, Lawrence, & Friedrich, 2016). Although the primary radiography discipline encompasses many areas of competency, multiple imaging technologies and specializations have been developed that use electromagnetic energy that spans both ends of the electromagnetic spectrum using both ionizing and non-ionizing methods to image the human body. These are referred to as post-primary disciplines or modalities. Radiographers acquire a unique set of skills in each modality as each has specific protocols, technical considerations, and hazards. Expertise in a modality must be achieved to minimize risks to the patients and the providers. Some of these modalities include; cardiac-interventional radiography, cardiovascular radiography, computed tomography (CT), magnetic resonance imaging (MRI), mammography, nuclear medicine, positron emission technology (PET), PET-CT, PET-MR, radiation therapy, sonography, vascular-interventional radiography, and many combinations of two or more of these. The ARRT has 14 post-primary categories listed. Among approximately 330,000 registered technologists in the United States, only 183,000 hold a post-primary certification (Census, 2018). Combined with growth in advanced imaging technology use, demand for technologists to become specialized either during or after their initial radiology education has also increased. From 2017 to 2018 CT and MRI scans in the United States alone rose from 119 million to 127 million scans per year (OECD, 2019a; OECD, 2019b).

In addition to increased demand for advanced modalities, multiple uses for the different modalities has extended into many other areas of the healthcare regimen to include interventional procedures, therapeutic procedures, and surgical procedures within imaging suites and within surgical suites (Adler & Carlton, 2016; Beardmore, Woznitza, & Goodman, 2016; Pieterse et al., 2016). As a result, radiographers are tasked with greater decision-making requirements. Students must be confident in their abilities before entering these environments to ensure accurate performance in the procedures and prompt reaction to emergencies or to errors.

Additionally, radiologic technologists who perform these procedures alongside radiologists or with surgeons expand their skills into areas previously performed by other healthcare professionals, such as advanced patient care, surgical methods, and pharmacology. The variability of skill required of the radiographer presents challenges in educating radiology students. Covering all aspects, modalities, and scenarios is not feasible in a four-year radiology program and less in programs that only offer associates degrees.

In response to limited time and/or resources, actual practice with the different modalities and with advanced patient care procedures is usually achieved with actual patients when the student is in the clinical environment, and many times this is achieved only after the student has graduated (Watson & Odle, 2013). The increased risk of students and radiographers performing these advanced procedures for the first time on actual patients is contrary to the medical safety movement that began in the late 1990s

(IOM, 1999; Watson & Odle, 2013). As a way to meet the challenge of time and space, several radiology programs have pursued online learning to expand their curriculum. Midwestern State University (MSU) has had a distance learning radiology program since the early 1970s, and over time has expanded their online education programs. There are several programs with varying levels of online instruction. These include an online bachelor completion program with a continuous enrollment of approximately 300 students, graduating about 100 per year; an entry-level program consisting of approximately 100 students per semester, who have a mixed curriculum of online and face-to-face instruction and who continue their learning completely online while in the clinical phase of the program; and, a graduate-level program consisting of approximately 40 graduate students per year in a masters hybrid program (C. Snyder, personal communication, December, 2018). Online programs bring advanced education to students who have already begun their clinical rotations and who are no longer on campus, and they also provide avenues for professionals to return for bachelor completion and graduate completion programs who cannot travel or take time from work. Additionally, the online delivery is beneficial for professionals in the field seeking to expand their expertise to meet the increasing need for multi-modality technologists. Although online learning fills the gap for time and space, it does not replace actual hands-on learning that challenges the student’s decision-making abilities within the healthcare setting. Application of didactic material is critical when providing patient care with advanced technology.

Statement of the Problem

When the IOM published their study, which revealed a large number of medical mistakes within the United States, a movement began to improve the quality and safety of care delivered to patients (IOM, 1999). Since this movement began, regulating bodies, professional organizations, and the general public have increased their expectations of healthcare educators to strengthen professional programs to address safety concerns (ACICBL, 2011; IOM, 2003; Martino & Odle, 2008). However, an influx in imaging technology and procedures, and increased demands upon the radiographer to perform continues to increase the risk of harm for patients and providers. Although the introduction of online education in the radiology profession broadens the reach for needed advanced education, radiology education programs need ways to improve the level of learning in online courses in advanced radiology modalities. The problem in this study relates to the exploration of innovative teaching methods that will aid in current and future demands in radiology.

Purpose

The purpose of this mixed methods case study is to investigate the design of virtual scenario-based branching simulations to enhance the learning experiences of online radiology students enrolled in undergraduate advanced modality courses, Magnetic Resonance Imaging Applications, and Principles of Computed Tomography, in which satisfaction and confidence in learning and in decision-making abilities are important elements. This innovative teaching strategy is emerging in nursing and physician education programs (Butina, Brooks, Dominguez, & Mahon, 2013; Elledge, Houlton, Hackett, & Evans, 2018), however, efforts in allied health programs, and, specifically radiology technology education, have been limited (Thoirs, Giles, & Barber, 2011).

Research Questions

There were two research questions guiding this study.

1. For the group of advanced imaging radiology students in this study, how does the design of the virtual scenario-based branching simulation impact the students' satisfaction with the learning experience?
2. For the group of advanced imaging radiology students in this case study, how does a virtual scenario-based branching simulation impact the students' confidences in their ability to make appropriate decisions in real-world practice?

Research Design

The research method proposed to answer the questions is a mixed methods case study design. A rich understanding of an educational intervention in a unique educational program is desired. Yin (1994) stated, "…case studies are the preferred strategy when "how" or "why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context" (p. 1). Case study design can provide an exploration of the events of a phenomenon within the context in which it occurs (Yin, 2009), which lends well to the research questions in which the perceived impact of an intervention within an online radiology course is the focus.

Limitations and Delimitations

Because of the uniqueness of the population in the study, limitations include a small sample size, time constraints, and instructor as researcher for a portion of one course section. Additionally, a limitation of the case study design is that generalization of results may be limited since the study is focusing on one group.

Delimitations include the exclusion of allied health students outside of radiology and radiology students who are not in advanced imaging courses. These will be eliminated from the study as the intervention is designed for advanced imaging curricula. Additionally, radiology students from institutions outside of Midwestern State University were eliminated so that an understanding of the intervention within the particular context could be explored. The data from outside of the MSU program may not be as robust as data from within, as the virtual scenario-based simulations were designed specifically to follow the MSU radiology curriculum within the online program.

CHAPTER TWO: LITERATURE REVIEW

This mixed methods case study integrates an online instructional design method with virtual scenario-based simulations, spurred by the need to improve upon the quality of healthcare education to provide better patient outcomes. The review of the literature focused on four areas that contributed to the reasons for, the choice of, and the design of a product developed for this study. As radiology specific education research is limited, and as radiology is included in the larger group of healthcare professionals, a broader scope encompassing evidence from all healthcare research is warranted. First, a review of the history of healthcare safety describes recommendations for innovative educational strategies when training 21st-century healthcare students. Next, teaching strategies were reviewed that were described by recommending healthcare agencies for explicit learning needs for healthcare providers. Third, a review of simulation-based instructional design strategies that have been used by different healthcare disciplines was performed. Lastly, scenario-based instructional design methods in a virtual context were studied.

Healthcare Safety and Education

Initially, the impetus for change in healthcare safety practices began with the publication of a report in 1999 by the Institute of Medicine (IOM, 1999), “to Err is Human”. The report set into motion transformations in healthcare practices, regulations, and education that have been ongoing since. In the report the IOM informed the public of enormous numbers of deaths that resulted from medical errors each year, estimating as many as 98,000 in the United States alone at that time. Although much attention has been given to the effort for many years, follow up reports have suggested there has been no change in the number of iatrogenic deaths (deaths occurring from medical treatment). Makary and Daniel (2016) estimated an increase in these deaths from the numbers provided in 1999 and that there could be as many as 251,000 American deaths in 2016 alone. The exact causes of these deaths have been difficult to track as the effects of errors may take time to emerge and may be overlooked by the patient's initial or subsequent disease processes (James, 2013; Makary & Daniel, 2016). In radiology, errors in the use of ionizing radiation may not present until months or even years after exposure. A recent example of incorrect safety protocols that were not discovered for 18 months, caused an extreme case of overexposure in 206 patients before it was linked to patient symptoms (Kuehn, 2010). Only after some patients began experiencing skin redness and losses of patches of hair, did they discover patients had received eight times the normal dose from their computed tomography (CT) exams performed months and in some over a year earlier. Many of these patients suffered from acute injury and all of them are now at an increased risk of developing certain types of cancer in their lifetime (Kuehn, 2010). In an industry where errors are not always immediately known or may be masked by other etiology, it is difficult for educators to determine which course of action would be best to prepare their students.

For guidance, the medical community has begun to look to other high-reliability professions in which exact causes of human error are more readily tracked (Hines, Luna, Lofthus, Marquardt, & Stelmokas, 2008). High-reliability organizations are organizations that have been able to achieve quality outcomes in complex, high-hazard, or high-risk environments where unexpected events and the potential for error and disaster is increased (Weick & Sutcliffe, 2001), such as the military, the aviation industry, and the nuclear power industries. In those industries, cognitive errors have been the focus of safety for some time (Flin, O'Connor, & Mearns, 2002). To mitigate human error in those industries the emphasis has been on the restructuring of training processes using educational technologies, such as simulators, serious games, and branching-scenarios. Their use of educational technology strategies has been shown to improve high order thinking and metacognitive skills (Flin et al., 2002). In healthcare, it has been suggested that fatal errors are a result of a lack of these skills in the providers (James, 2013; Stark & Fins, 2014). James (2013) found in the literature many commonalities in fatal errors that may have been prevented with improvements in the thinking skills of the provider. He categorized these into several common themes; communication, commission, omission, contextual, and diagnostic. Stark and Fins (2014) suggested that rising numbers of research on these types of cognitive medical errors give concern and reason for educators to strengthen the critical-thinking processes of medical professionals calling it a "moral and professional duty" (p.1). Facione and Facione (2008) also focused on cognitive skills relating professional judgment to the use of critical-thinking skills stating, "Lives depend on competent clinical reasoning. Thus it is a moral imperative for health care providers to strive to monitor and improve their clinical reasoning and care-related judgments" (p. 1). Thus, as an educator, the use of teaching methods that focus on improving cognitive processes may help mitigate many medical errors. This has not only been suggested by many researchers but has also been suggested by many healthcare governing agencies.

A continuing safety effort by the IOM (Institute of Medicine) resulted in a subsequent report published in 2003, *Health Professions Education: A Bridge to Quality*, which focused on transforming education to address the ongoing safety issues (IOM, 2003). Among many observations that were made, some included were that healthcare students were not proficient in resource gathering, they were not proficient in the application of those resources, and students were not given opportunities to analyze root causes of errors and other quality problems (IOM, 2003). The IOM recommended a shift in educational approaches from lecture-based delivery to problem-based and self-directed learning strategies, both strategies that are known to build the cognitive processes of students. Additionally, as one of their five major recommendations, the integration of information technology in education was also proposed (IOM, 2003).

The radiology community responded in 2004 by forming the ASRT (American Society of Radiologic Technologists) Task Force on New Educational Delivery Methods to help radiology educators make a transition from, “content experts to context experts” (Martino & Odle, 2008, p. 31), through the use of new educational strategies and technologies. The task force focused on new technologies for clinical and didactic settings that would improve the delivery of radiology education in a manner that would foster problem-based thinking, student-centered learning, and lifelong learning (Martino & Odle, 2008). Virtual simulations, eLearning, distance education, online instruction, hybrid courses, computer-aided education, and portable electronic devices were all reviewed and recommended (Martino & Odle, 2008).

The Advisory Committee on Interdisciplinary, Community-based Linkages (ACICBL) also addressed new educational strategies in its *11th Annual Report to the Secretary of Health and Human Services* (ACICBL, 2011). Extensive attention was focused on fostering the development of lifelong learners. They weighed much of their research on the Macy Foundation's (2010) characterization of lifelong learning as one's ability to resolve issues through inquiry, resource identification, and independent/continual assessment of one's own learning needs (ACICBL, 2011). They suggested to healthcare educators this should be accomplished using eLearning technologies, such as e-portfolios, multimedia, virtual patients, web-based learning, and other educational technologies that would assist in the expeditious dissemination of new knowledge (ACICBL, 2011). Common among these agency recommendations are a focus on educational strategies that invoke both high order thinking and self-directed learning skills (see Table 1).

Table 1. Recommendations for Educational Strategies

Organization	Year	Publication	Recommendations
Institute of Medicine (IOM)	1999	"to err is human"	Raise awareness of safety concerns, Look to other industries to improve safety in healthcare
IOM	2003	Health Professions Education: A Bridge to Quality	Problem-based learning, Self-directed learning, Information technology
American Society of Radiologic Technologists (ASRT) Task Force on New Educational Delivery Methods	2004	New Models, New Tools The Role of Instructional Technology in Radiologic Sciences Education [white paper]	Problem-based thinking, Student-centered learning, Lifelong learning, Virtual simulations, eLearning, Distance education, Online instruction, Hybrid courses, Computer-aided education, and Portable electronic devices
Advisory Committee on Interdisciplinary, Community-based Linkages (ACICBL)	2011	11th Annual Report to the Secretary of Health and Human Services	Lifelong learning, eLearning technologies, such as e-portfolios, multimedia, virtual patients, web-based learning, and other educational technologies that would assist in the expeditious dissemination of new knowledge

Strategies for Teaching Healthcare Students

Since many recommendations in the literature and by these organizing agencies for explicit learning needs for healthcare providers include a strong focus on strengthening cognitive processes, a search for how this may be achieved with healthcare students was needed. A review of the definition of critical thinking, and explorations of problem-based learning and deliberate practice (DP), as they pertain to the healthcare field, were performed.

Critical Thinking

The goal of effective healthcare education is founded on the principles of preparing the student to safely and effectively apply their disciplinary knowledge and practical experience to perform sound clinical reasoning and problem-solving skills when delivering care to patients (Facione & Facione, 2008). There are several variations of the definition of critical thinking, however, a collective effort by Facione (1990) and the American Philosophical Association defined it as a purposeful, self-regulatory, nonlinear, and recursive cognitive process that a person uses to make a decision about what to do in a given context (p.3).

Using scenario-based simulation technology can recreate real-world experiences that can help a student build his or her critical thinking skills (Cook, Erwin, & Triola, 2010; Jamkar et al., 2007). Abuzaid and Elshami (2016) found that when using virtual patient scenarios as an online virtual teaching experience for radiology physician interns, learning outcomes were positive and critical thinking skills were challenged and improved. Residents worked through the scenarios as if they were working with actual patients. They were able to control which scenarios they worked with, were able to draw from relevant resources, were able to reflect, and thus were able to make informed decisions.

In radiology technology education, the use of critical thinking educational strategies is limited. A survey in 2012 of radiology program directors in the United States found that even though the use of critical thinking is perceived as a necessity for the profession, and that the perception of radiology directors own level of critical thinking skills were high, their perceived level of confidence to instill and assess student critical thinking was mediated by their level of education (Kowalczyk, Hackworth, & Case-Smith, 2012). This imparts a need for the development of innovative teaching strategies.

Halpern (1998) suggested critical thinking is a product of metacognition, and Kuhn (1999) stated that metacognition is the key feature of critical thinking. Critical thinking and metacognitive strategies are similar in that they are both ways of *thinking about thinking*, however critical thinking is analyzing, assessing, and improving thinking in a particular domain, while metacognition refers to one's *awareness* of their thinking processes that can be used to complete a task as well as the ability to regulate those processes (awareness and control of cognition) (Schunk & Zimmerman, 2008). Magno (2010) reported that student scores from the Metacognitive Assessment Inventory (MAI) and the Watson-Glaser Critical Thinking Appraisal (WGCTA) showed a significant path from metacognition to critical thinking.

Metacognition involves a deeper understanding of one's knowledge about their own cognition, and is defined by Schunk (2012) as the "deliberate conscious control of cognitive activity" (p. 286). Many researchers define metacognition using two common components; knowledge of cognition and regulation of cognition (Schraw & Moshman, 1995; Schunk, 2012). Knowledge of cognition is an awareness of one's own knowledge about what learning strategies, skills, and resources are required to complete a particular task, and regulation of cognition is knowing when and how to use these cognitive strategies for the appropriate tasks (Schunk, 2012, p 286). Both are important in making decisions in self-directed learning tasks as well as making decisions in a clinical situation.

Developing a student's critical thinking and metacognitive skills collectively could guide the learner to become a clinician who is flexible, adaptable, and who would engage in lifelong learning.

Problem-based Learning

Problem-based learning (PBL) is a student-centered pedagogy that provides the student with meaningful practice that also encourages higher-order thinking through the design of solving problems that are related to future practice. It is an active learning strategy in which the learner identifies and analyzes a problem, searches for resources to solve the problem, produces a solution, critically appraises the solution, and engages in self-assessment (Neufeld & Barrows, 1974).

Problem-based learning in healthcare education has been seen as a way to transition from lecture-based curricula to innovative teaching practices (Tavakol & Reicherter, 2003). The concept emerged in the 1960s as a better way to inform medical students who were disengaged in lecture-based curricula and to invoke self-directed learning and metacognitive skills (Neufeld & Barrows, 1974). In an attempt to relate metacognition to problem-based learning simulations, Oh (2016), found that students who possessed high metacognitive abilities before the problem-based learning task show a significant difference in the effectiveness of the exercise. Although this benefited students who already had high metacognitive skills the study also showed an increase in the metacognitive abilities of those who had low incoming metacognitive abilities.

Although typically seen in a classroom or simulation lab as a face-to-face approach, new interactive educational technologies can provide the student with problem-based learning activities outside of the classroom. For example, Benedict, Schonder, and

McGee (2013) found virtual simulations using virtual patients with branching scenarios using a problem-based learning approach was effective in advanced therapeutics courses. In addition, in a social work context video case-scenarios that were provided in an eLearning environment using a problem-based learning approach were also successful (Ballantyne & Knowles, 2007). Jin and Bridges (2014) meta-analysis of 28 studies in medicine, dentistry, and speech and hearing showed positive outcomes for authentic problems and/or case contexts for PBL, however, it was stated a limitation found was cumbersome scenarios. The technologies used in their studies to incorporate PBL were learning software and digital learning objects; interactive whiteboards and plasma screens; and learning management systems (LMSs).

Deliberate Practice

In addition to problem-solving and critical thinking, it is desired that healthcare providers become experts in their fields to mitigate errors caused by inadequacies in training and learning. Benner, Hughes, and Molly (2008) described expertise as a sense of salience the clinician develops over time as the learner moves from novice practice to more expert practice. Deliberate practice is the framework developed by K. Anders Ericsson that is most often used in medical education to assist the learner in the transition from novice to expert (Ericsson, 2004). This framework involves the intense repetitive practice of intended cognitive or psychomotor skills in a specific domain with continuous reflection and assessment. It has been described by the medical community as a way to engage one's critical thinking and problem-solving skills (McGaghie, Issenberg, Cohen, Barsuk, & Wayne, 2011). With limited time, space, and faculty resources for laboratory-based simulations, virtual simulations may effectively provide an avenue for self-directed deliberate practice as they have the capability to include repeated practice, immediate feedback, and allow the learner to reflect on what worked or did not work (Cook et al., 2010), challenging the learner's metacognitive skills.

Simulation-Based Learning

Simulation-based learning is an innovative teaching method that is prominent in healthcare education programs for physicians, nurses, and in allied healthcare professions from undergraduate work to graduate work and further into advanced training and continuous assessments (Alinier & Platt, 2014; Cook et al., 2011; Ziv, Wolpe, Small, & Glick, 2003). Although much of the literature on simulation in healthcare education focuses on physical simulation as compared to virtual simulation, an understanding of the tenets of simulation in all environments are needed to inform the practice in a virtual space.

Simulation-based learning is a learning model that exploits the benefits of experiential learning to achieve educational goals using a simulated environment or activity. In healthcare, this educational strategy allows students to practice both their technical and non-technical skills in a safe environment with no danger of harming the patient (Ziv et al., 2003). Cook et al. (2012) defined technology-enhanced healthcare simulation (TES) as, "an educational tool or device with which the learner physically interacts to mimic an aspect of clinical care for the purpose of teaching or assessment" (p. 308). The difference in the literature between technology-enhanced simulation and simulation is the absence of standard patients, or human actors, in TES. There are several variations of simulation-based tools found in healthcare research, such as static mannequins, plastic models, standardized patients, live animals, human cadavers, virtual reality simulators, computer-enhanced full-body mannequins, and more (Cook et al., 2011; Damassa & Sitko, 2010; Miller, Lee, Rogers, Meredith, & Peck, 2011; Ziv et al., 2003). However, much repeated in the literature, Gaba (2004) cautions that a simulation is a "technique-not a technology-to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real-world in a fully interactive manner" (p. i2), thus requiring much exploration into the design of these activities.

Just as Gaba has focused on the technique, Reedy (2015) also suggested instructional designers take into consideration the effects of cognitive load theory when implementing a simulation-based approach. Cognitive overload is a state in which the learner becomes unable to process new information either because the difficulty of the task is inappropriate for the learner's current level of knowledge (intrinsic load and germane load), or the task has been inappropriately presented or designed (extraneous load) (Reedy, 2015). Simulation research describes levels of realism and complexity as fidelity. Reedy (2015) suggests novice learners be provided with low-fidelity simulations, and, as the student progresses in their knowledge, increasing levels of fidelity should then be introduced.

Fidelity

In healthcare education, varying levels and types of simulation have been used in training and in assessing clinical competence. Borrowing from Miller's Pyramid of assessment of clinical skills, competence, and performance, a model of assessment ranges from 'knows' (knowledge), to 'know how' (competence), to 'shows how' (performance), to 'does' (action) (Miller, 1990). Schuwirth and van der Vleuten (2003) categorized simulation-based assessment methods using Miller's levels and by correlating assessment with the levels of fidelity of simulation activities.

Low-fidelity

In a low-fidelity simulation, there is a lack of realism or situational context and the simulation is incapable of providing feedback (Seropian, Brown, Gavilanes, & Driggers, 2004). After gaining the background knowledge from lecture or study, the goal of a low-fidelity simulation is for the learner to gain the 'know how' of a technical skill or knowledge and then proceed to the 'show how' level of competence. Examples include the use of a prosthetic arm for the insertion of an intravenous catheter and the use of a static mannequin for the performance of CPR.

Moderate-fidelity

A moderate-fidelity simulation aims to be a culmination of several procedures put together to resemble a simple clinical scenario which tests the student at the 'show how' level up to the 'performance' level for clinical competence. The learner applies the knowledge and competence previously learned. Moderate-fidelity simulations involve a more complex task than in the low-fidelity simulation providing the student with more than a one-dimensional experience (Jeffries, 2007). In radiology, a moderate-fidelity simulation activity includes the use of anthropomorphic phantoms (for imaging different body parts) used in combination with x-ray equipment simulators to provide actual images that can be manipulated by technique and position. To assess patient care aspects of the radiology experience, role-play is also used; however, actual use of the radiation-producing equipment on the actors limits the level of realism.

High-fidelity

A high-fidelity simulation incorporates a high level of realism that can be used to evaluate the ‘performance’ and ‘does’ tiers of Miller’s pyramid (Schuwirth & van der Vleuten, 2003). Originally the ‘does’ level was intended for working with actual patients, however, the level of realism now available with simulation technology may come close to the experience of working with real patients (Munshi, Lababidi, & Alyousef, 2015). High fidelity examples include simulation laboratories that incorporate digital manikins in which the manikins can be programmed with responses in vital signs and reactions, hiring an actor or actors to recreate a medical scenario, or using interactive operative suites with actual equipment and haptic feedback surgical tools. These interactive simulations, or human-in-the-loop simulations, require the learner to become a participant in the simulation. The simulator reacts according to how the learner responds. Interaction provides the learner with opportunities for trial and error based on consequences and feedback. High fidelity simulations lend well to scenario-based learning and are often an integral part of the scenario-based instructional design. They have been used in training multidisciplinary trauma teams (Falcone et al., 2008), training nurses for psychiatric encounters (Murray, 2014), preparing for mass casualties in disaster situations (Scott et al., 2012) and more. High fidelity simulation is limited in the research for radiographers, however, in the management of adverse contrast media reactions, improvements in skill and improved perceptions of competence have been seen (Aura, Jordan, Saano, Tossavainen, & Turunen, 2016; Wang et al., 2017).

Educational Outcomes

Educational outcomes for simulation education have varied throughout the literature. While Epstein and Hundert (2002) stress that no single-simulation-based assessment will be able to assess the entire range of medical competencies, Cook et al.'s 2011 meta-analysis of 609 studies of simulation in healthcare professions education revealed positive effects. When compared to no intervention, simulation-based learning was consistently associated with large effects for outcomes of knowledge, skills, and behaviors, and moderate effects were seen for patient-related outcomes (Cook et al., 2011). Likewise, a subsequent meta-analysis of 92 studies in which technology-enhanced simulation was compared to other instructional modalities, authors found technology-enhanced simulation was associated with higher learning outcomes and they too reported statistically significant differences for knowledge, process skills, and product skills as well as improved student satisfaction (Cook et al., 2012). When using a deliberate practice framework for simulation-based medical education, McGaghie et al.'s (2011) meta-analysis revealed that specific clinical skill acquisition goals were greatly improved compared to traditional clinical medical education. A look at specific venues revealed similar results. In a meta-analysis of 86 articles for simulation-based learning for emergency room learners moderate or large effects were shown as compared to no intervention, and small and non-significant benefits were seen in comparison with other instruction (Ilgen, Sherbino, & Cook, 2013), and in a meta-analysis of 57 studies for training healthcare professionals in pediatrics it was revealed there were large outcomes of knowledge, non-time skills, behaviors with patients, and time to task completion as compared to no intervention (Cheng, Lang. Starr, Pusic, & Cook, 2014). Cheng et al.

(2014) also noted that in comparison with the use of high versus low fidelity simulators small to moderate effects for higher fidelity simulators were seen. Additionally, Ma et al.’s (2011) review of 20 studies for a particular procedure that is often performed by an interventional radiologist using sonography or fluoroscopy, the insertion of a central venous catheter, simulation based-learning was associated with improvements in learner outcomes, and select clinical outcomes, but no significant risk reduction for arterial puncture or catheter-related infections was seen (Ma et al., 2011).

Best Practices for Simulation Design

With the variability of simulation technologies, there has also been various reporting in the research defining characteristics of simulation design that leads to learning effectiveness (Cook et al., 2010; Cook et al., 2012; Zendejas, Brydges, Wang, & Cook, 2013). Two in depth-meta analyses reviewing healthcare simulations were identified and comparisons of best practices revealed similarities in findings (see Table 2). Okuda et al. (2009) found 10 common characteristics among the healthcare literature of high-fidelity simulations that lead to effective learning, and similarly, McGaghie, Issenberg, Petrusa, & Scalese (2010) found in their review of the literature 12 features and best practices for simulation-based medical education (SBME) (Table 2).

Table 2. Similarities in Research for Best Practices in Medical Simulation Design

Features of High-Fidelity Medical Simulations that Lead to Effective Learning (Okuda et al., 2009, p. 333)	Features and best practices for SBME (McGaghie et al., 2010, p. 52)
1. Mechanism for repetitive practice	1. Deliberate practice
2. Ability to integrate into a curriculum	2. Curriculum integration
3. Ability to alter the degree of difficulty	3. Mastery learning
4. Ability to capture clinical variation	4. Transfer to practice
5. Ability to practice in a controlled environment	5. High-stakes testing
6. Individualized, active learning	6. Skill acquisition and maintenance
7. Adaptability to multiple learning strategies	7. Simulation fidelity
8. Existence of tangible/measurable outcomes	8. Outcome measurement
9. Use of intra-experience feedback	9. Feedback
10. Validity of simulation as an approximation of clinical practice	10. Educational and professional context
	11. Team training
	12. Instructor training

Virtual Simulation Technology

Although the medical community has used simulation learning for a long time, the adoption of technology-enhanced simulation has been slower than in other high-reliability professions, such as aviation, the military, and the nuclear power industry (Ziv et al., 2003). However, technology-enhanced simulations have recently gained momentum in healthcare as the need for safe learning environments has increased, and as advances in technology have led to increased availability of quality simulators (Damassa & Sitko, 2010). Simulation technologies that are becoming more prevalent include computer-enhanced mannequins, computer-based or computer-driven simulators, virtual reality simulators, and serious games (Damassa & Sitko, 2010).

Advanced human-computer interaction, or virtual reality, is growing in popularity among physician and nursing based programs and has been seen in only some radiology and other allied healthcare studies. Virtual simulations are similar to the varying degrees of traditional simulations as the level of realism and user interactivity varies with the design (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005). The definition of virtual simulation is sometimes intertwined with the definition of educational games as the virtual simulation can be designed to incorporate an interactive game-like quality. Sitzmann (2011) referred to these as simulation games and described them as, "…instruction delivered via a personal computer that immerses trainees in a decision-making exercise in an artificial environment in order to learn the consequences of their decisions" (p. 492).

As virtual capabilities have increased, a number of new options have become available, such as interactive 3-dimensional computer graphics models (3DCG), interactive online collaborative learning environments such as, 3D multi-user virtual environments (MUVES) and massively multiplayer online games (MMORGS), computer-based free-range or linear scenarios (virtual patients), semi or fully immersive technology, and computer-based interactive complex scenarios with a branching scenario design. Anatomical representations using 3-dimensional computer graphics (3DCG) are interactive virtual models of the human body. This technology, such as the Anatomage table, and augmented reality apps like Visible Body, allows users to dissect and interact with specific virtual body parts obtained from actual CT and MRI scans and cadaver images and are useful in the knowledge gaining tier of Miller's clinical assessment clinical skills, competence, and performance pyramid, and may be used for the 'knows how' tier.

3D multi-user virtual environments (3D MUVEs), such as Second Life, and massively multiplayer online games (MMOGs), such as World of Warcraft or Runescape have also been introduced in healthcare education (Damassa & Sitko, 2010; Miller et al., 2011) and have the ability to develop collaborative learning, situated cognition, and problem-solving (Wang & Burton, 2013). Although popularity in MUVEs and MMOGs have encompassed the gaming world, and MUVEs are steadily increasing in the healthcare education community (Damassa & Sitko, 2010), they are still not well researched for use with healthcare education (Miller et al., 2011).

Another technology is haptic feedback technology. These simulation tools allow the learner to experience a virtual activity with an added sense of touch and response. These have been used in physician training for practicing virtual surgeries with instruments that respond with motion (Panait et al., 2009; Van der Meijden & Schijven, 2009). Laparoscopic virtual surgery simulators and interventional radiology simulators have been used to assist physicians in developing both technical and process skills (Panait et al., 2009). Particularly in radiology, these systems can provide the physician with a force/tactile reflecting mechanism for the deliberate practice of difficult or rare procedures, such as of carotid artery stenting and contralateral iliac angioplasty/stent procedures (Gould, 2010), These systems incorporate a more heightened level of realism and can be used to build technical skills for performing surgeries and for integral dentistry work.

Another development in immersive virtual technology that can be combined with haptic systems involves 3D virtual reality in which the user dons a head-mounted display for a fully immersive visual experience (Jensen & Konradsen, 2017). Although there has been much interest in the technology for healthcare students, Jensen and Konradsen (2017) reviewed the research currently available and have found benefits for skills acquisition in certain situations, such as, cognitive skills related to remembering and understanding spatial and visual information and knowledge; psychomotor skills related to head-movement, such as visual scanning or observational skills; and affective skills related to controlling emotional response to stressful or difficult situations (p. 13). However, in most other situations they found little benefit was seen over less immersive technology and standard instruction.

Virtual patient scenarios and virtual patients (VPs) have been increasing in availability and popularity and are apparent in the literature, particularly in nursing and physician training (Consorti, Mancuso, Nocioni & Piccolo, 2012; Cook et al., 2010). As radiologic sciences have only a handful of attempts found in the literature (Abuzaid &

Elshami, 2016; Schinman & Trad, 2016) it is necessary to draw from these and other professions when developing similar activities for radiology students.

Educational Virtual Environments

With positive results for technology-enhanced simulations in general, it is necessary to consider design characteristics and teaching and learning theories that may inform the design of healthcare education simulations delivered using computer-based virtual environments. The research has yet to provide a clear theoretical model for the design of educational virtual environments (EVE) (Mikropoulos & Natsis, 2011). However, in their review of 50 papers on EVE in varying disciplines with varying levels of fidelity that spanned 10 years (1999-2009) Mikropoulos and Natsis (2011) surmised that even though theory was not always explicitly stated, the affordances found in the literature align with the constructivist model. This is similar to the findings of Dalgarno and Lee's (2010) previous research on the design of 3D virtual environments, and Pinchevsky-Font and Dunbar's (2015) discussion of best practices for online teaching and learning in allied healthcare programs. In the constructivist model, learning is acquired through an active, contextualized process of constructing knowledge where learners are actively involved in a process rather than passively acquiring information. In addition to the constructivist model, EVEs also satisfy adult learning theory by aligning with self-direction, and situated cognition. Some of the affordances Mikropoulos and Natsis (2011) and Dalgarno and Lee (2010) outlined also align with independent scenario-based virtual activities include spatial knowledge representation, experiential learning, engagement, and contextual learning.

However, it is proposed that since technology-enhanced simulations and virtual simulations are similar enough to be combined in studies of effect, it can be reasoned that designs and concepts gained from healthcare simulations research (Table 2) may be transferable from generalized healthcare educational simulations to the virtual simulation environment (Cook & Triola, 2009; Okuda et al., 2009). Virtual simulations offer opportunities for deliberate practice in a safe environment that can assist in building the skills necessary to deliver safe effective care for real patients.

Scenario-based Learning

Although a simulation activity without scenario-based learning may be useful for the practice of certain technical skills such as equipment familiarization, radiology imaging critique, imaging anatomy familiarization, or recall of domain-specific knowledge, experiences that will challenge critical thinking and problem-solving skills requires a different approach. Scenario-based learning is an active learning strategy that uses case-based learning or problem-based learning to interactively engage the student in the learning process (Errington, 2009). Designed from a set of preplanned learning objectives, the student is presented with an authentic interactive scenario that reflects a real-life situation in which there is a complex problem that needs to be solved (Clark & Mayer, 2013). The scenario follows a storyline in which the learner becomes the actor, and, when provided with a complex experience becomes the facilitator of his or her own learning by analyzing the problem, planning a course of action, taking action, reviewing the response to his or her action, and reflecting on the consequence of those actions (Clark & Mayer, 2013).

Scenario-based learning is based on the principles of situated cognition and situated learning theory (Errington, 2009). Situated cognition is the idea that knowledge is better understood if it is acquired within the context, culture, and activity in which it is developed and used (Brown, Collins, & Duguid, 1989). Salas, Wilson, Burke, and Priest (2005), pointed out that the use of content-valid scenarios is critical in high-risk environments. For example, the military uses them to train soldiers in a variety of areas, such as cultural relations, leadership training, and areas in which the soldier must become skilled in critical decision making to ensure the success of the mission (Gordon, van Lent, van Velsen, Carpenter, & Jhala, 2004).

Although scenario-based learning in healthcare education has typically been performed in the classroom or clinical laboratory, in a comparative meta-analysis, Gavgani, Hazrati, and Ghojazadeh (2015) found digital-based scenarios were just as consistent in promoting clinical reasoning and critical thinking as paper-based scenarios, and were actually considered more efficient, and were consistently viewed as more favorable by the students. An overwhelming increase in engagement suggested students were better able to place the scenario in context and become part of the problem-solving team rather than perform as an outside player. Scenario-based learning in a virtual environment was defined by Clark and Mayer (2013), as, “Scenario-based e-learning is a preplanned guided inductive learning environment designed to accelerate expertise in which the learner assumes the role of an actor responding to a work-realistic assignment or challenge, which in turn responds to reflect the learner’s choices” (p. 5). Clark and Mayer (2013) suggest scenario-based eLearning environment characteristics include: 1) a pre-planned environment, 2) inductive rather than instructive learning, 3) guided instruction, 4) the incorporation of instructional resources, and 5) a focus on invoking expertise (p. 5-7).

Salas et al. (2005) suggested the design of scenarios in simulations is critical, particularly for instances of catastrophic consequences and for rarely performed procedures. They suggested the design of the scenarios be constructed from the learning outcomes using a storyboard, and should be realistic with varying levels of difficulty. To assure scenarios are as close to the real event as possible, Clark and Mayer (2013) suggested content for these scenarios should be obtained by interviewing an expert or team of experts. Additionally, Cook et al. (2010) recommended that a focus on the design of these scenarios that can improve learning outcomes should include: (a) repetition until demonstration of mastery (deliberate practice), (b) advanced organizers (metacognitive skills), (c) enhanced feedback (deliberate practice and metacognitive skills), and (d) explicitly contrasting cases (critical thinking skills) (p. 5-7).

Similar to the fidelity levels in simulations, the delivery of a virtual scenario can be tailored to the level of the students. Using virtual technologies enables the educator to vary the design of these scenarios from simplistic, to complex, to branched, or they can be mixed. As an example, Cook et al. (2010) categorized the types of patient case progressions in virtual patient scenarios as either:

1. *free*, in which the virtual patient does not progress with the student, for example, the patient status does not change as the learner gathers information, so the learner may be solving problems related to the patient condition, however, no consequences or changes emerge in the patient despite the student’s actions,

2. *linear*, in which the patient evolves over time, regardless of the learner's decisions, for example, the patient may steadily deteriorate regardless of how the student responds, or
3. *branching* in which the patient evolves with the learner's decisions requiring the learner to think critically and draw upon previous knowledge to make a decision about what should be done (p. 1590).

In a branched design, which is what was used in this study, it is possible the scenario could become quite complex. Branching of virtual simulations takes a narrative approach a step further requiring the student to make decisions about the clinical situations, and, depending on his or her choices, the scenario changes and becomes a web of individualized interactive experiences for the student (Gordon, 2009). Gordon (2009) describes branching scenarios as a type of outcome-based simulation activity that includes a set of characters and a storyline with causally related events that emulates fictional or non-fictional events. Cook et al. (2010) considered the branching attribute as moderate in terms of individualized learning, and, when discussed in the context of a virtual branching simulation, many have described the activity as a problem-solving strategy that encourages the critical thinking and decision-making skills of the learner (Gordon, 2009; Smith, Mohammad, & Benedict, 2014; Talbot, Sagae, John, & Rizzo, 2012).

Typically, branching scenarios have been delivered as paper-based or classroom-based scenario exercises. However, virtual technologies offer educators the ability to create branching scenarios, which enhance learning through multiple scenarios with multiple outcomes. Virtual technologies also provide opportunities for more engaging and challenging atmospheres that may invoke more game-like qualities (Karakuş, Duran, Yavuz, Altintop, & Çalişkan, 2014). Game-informed elements similar to serious games provide the learner with challenge, repeatability, and the achievement of a goal, which have been said to increase motivation (Kapp, 2012).

An additional advantage to delivering a scenario in a virtual environment is that it allows the educator to provide open access to these scenarios that can encourage repetitive skill practice, which has been a guiding principle in the acquisition of expertise (Ericsson & Charness, 1994). The most studied use of these in healthcare has been in the form of virtual patients, or interactive patient scenarios, which include simulating procedures, history and physical exam indications, and signs and symptoms. However, even though virtual branching scenarios in healthcare have become increasingly popular in high-level professional programs such as pharmacy and physician training, research on its use in allied healthcare professional education is limited, specifically in undergraduate radiologic science programs (Cook et al., 2010; Gordon et al., 2004; Smith et al., 2014).

An overarching goal for the inclusion of virtual scenario-based branching activities is founded on the abilities of the healthcare student to recall and apply information in an efficient and accurate manner, which has been effectively linked to patient outcomes (McGaghie, Draycott, Dunn, Lopez, & Stefanidis, 2011). It is important the radiology student develop strong domain-specific knowledge, specialized high-order thinking skills, and metacognitive skills to achieve accurate, safe performance of his or her skills with the ability to continue growing as a lifelong learner.

Digital Scenario-based Design

In addition to these suggestions, a design for scenario-based eLearning developed by Clark and Mayer (2013) describes six core components to think through when designing eLearning scenarios. These are task deliverables, a trigger event, case data, guidance and instruction, feedback, and reflection. The latter two, feedback and reflection, satisfy features also identified with effective medical simulation learning outcomes as well as the ability to provide an opportunity for building metacognitive skills (McGaghie et al., 2010; Schraw & Moshman, 1995).

Task Deliverable

The task deliverable is the objective of the scenario. Clark and Mayer (2013) suggest defining a clear outline of the objectives and clearly defining all items necessary for the learner to be able to resolve or complete the scenario. This includes the desired actions and decisions that will reflect critical thinking skills, the paths that would be determined to define successful or moderate completion, procedural skills that may need to be completed in a particular order, and any domain-specific knowledge that may need to be known prior to the learner's engagement with the activity (Clark & Mayer, 2013).

Simulation and game-based research suggest transfer is associated with the effectiveness of the task to align with the learning objectives (Ke, 2016; Shelton & Scoresby, 2011). Activity-goal alignment, as described by Shelton and Scoresby (2011), suggest that a game is more beneficial for learning if the intended pedagogy is properly embedded in the design. Similarly, Ke (2016) suggested that the targeted learning objectives also be aligned with domain knowledge.

Trigger Event

The trigger event is the initial start of the scenario. This is where the story begins and where the learner is provided with the setting and the specific event. In a virtual scenario, this would be the first page that provides the learner with the problem. This page gives the learner an opportunity to analyze the situation and review any background information needed to carry out the scenario. A unique approach described by Clark and Mayer (2013) as the "Murphy's Law Trigger" approach first provides the learner with the outcome to the scenario or similar scenario in which everything goes wrong. The learner is then virtually allowed to go back in time to correct the errors (p. 39). An additional approach to the design of this page comes from Ke (2016), who suggested that the drive for motivation should be accomplished through representations of the most fun part of the academic domain (p. 237). For healthcare students, this may involve actual representations (images or videos) of disease processes or catastrophic events.

Scenario Data

Scenario data, or scenario resources, provides the learner with unique data to the situation. Clark and Mayer (2013) suggest incorporating an area for students to save data if it will be needed for later analysis. This type of organization can provide the student with an opportunity for self-directed learning, as they will need to organize information so they may use it later to aid in solving the problem.

Guidance and Instruction

Guidance and instruction provide options for the learner to discover information to guide them through the scenario. However, too much guidance or too little guidance has been a determining factor in learning outcomes (Clark & Mayer, 2013). Looking to game elements, Ke (2016) found that if the guidance is cognitively demanding or is not directly integrated into the gameplay it may be intrusive and may affect learning engagement.

Scaffolding the level of guidance has been suggested as a way to encourage self-directed learning and metacognitive skills, and has been suggested as a way to reduce the possibility of cognitive overload (Clark & Mayer, 2013; Ke, 2016). Kornell and Finn (2016) emphasize the difference between self-regulated learning in an online environment as compared to classroom-based learning in that self-regulated learning is on the burden of the instructor in the classroom and vice versa. Scaffolding can be used in an online activity to ease the student into the self-regulated learning (SRL) processes. Clark and Mayer (2013) outlined several ways of scaffolding guidance in a scenario-based eLearning activity. These are: faded support, simple to complex scenario design, low to high number of choices, closed to open-ended responses, simple to full-screen navigation, slow introduction to access of tools or objects, worksheets for the organization of resources, high to low feedback, and collaboration in small teams (Table 3).

Table 3. Characteristics of a Scenario-based eLearning Environment

Suggestion	Explanation
Faded support	More guidance in the beginning and less as the student progresses.
Simple to complex scenarios	Each module includes a progression of simple to more complex scenarios. Increasing number of variables, increasing the amount of conflict in the data or including the number of unanticipated number of events.
Open versus closed responses	Limited choice responses or open-ended responses.
Interface navigation	Fewer options at a time on the screen as compared to full-screen display.
Training wheels	Limited functionality for some items at certain stages.
Coaching and advisors	Virtual agent offers hints on feedback and less help as the student progresses.
Worksheets	More guidance in the beginning and less as the student progresses.
Feedback	Each module includes a progression of simple to more complex scenarios. Increasing number of variables, increasing the amount of conflict in the data or including the number of unanticipated number of events.
Collaboration	Limited choice responses or open-ended responses.

Note: Information in this table was taken from Clark & Mayer, 2013, p.76-77

Self-directed Learning

Self-directed learning as described by Knowles (1975) is the ability of the learner to take control of his or her own learning through the continued diagnosis of his or her own learning requirements, by identifying resources for learning, applying appropriate learning strategies, and thorough evaluation of the learning outcomes (p. 18). Self-directed learners exhibit characteristics that overlap with metacognitive skills. With an influx of tens of thousands of medical research articles being published each year

(Holmboe, Ginsberg, & Bernabeo, 2011), it is imperative healthcare professionals continuously inform their practice. Self-directed learning has often been associated with the skills needed to develop as a lifelong learner, and, as such, has been a recommendation in the educational strategies for healthcare educators (ACICBL, 2011; IOM, 2003; Martino & Odle, 2008). Benedict et al. (2013) reported virtual patient cases strongly promoted self-directed learning and were as effective as traditional teaching methods. Virtual patients have been used in the education of nurses, physicians, dentists, pharmacists, veterinarians, physical therapists, and radiology physicians (Abuzaid & Elshami, 2016; Benedict et al., 2013; Cook et al., 2010).

Although it has been suggested that educators use new technologies as a bridge to developing lifelong learning skills, a meta-analysis by Brydges Hatala, Zendejas, Erwin, and Cook (2015) revealed that self-regulated learning (SRL), synonymous to SDL, has not been given attention in technology-enhanced medical simulation studies. They suggested educators may not have a full understanding of how to foster this type of learning and suggested using a previously successful model, the social-cognitive model of SRL (Schunk, 1999).

1. Observational-student observes the task
2. Emulative-student then practices with guidance
3. Self-control-student begins to perform the task independently with some guidance
4. Self-regulation-student adapts performance to various situations independently

This model can be accomplished by designing the scenario-based virtual simulation in a scaffolding framework similar to the guidance framework suggested by Clark & Mayer (2013) in Table 3; offering much guidance in the beginning either through instruction, cues, or videos, and then slowly reduce the amount of help requiring the learner to develop his or her own methods of data information collection.

Self-efficacy and Transfer

Zimmerman (1995) suggested a failure to self-regulate might lie in the self-efficacy of the student, stating that self-beliefs have an effect on self-regulatory processes, such as cognition, motivation, and affect. Similarly, Gegenfurtner, Quesada-Pallarès, and Knogler's (2014) meta-analysis of digital simulation-based training also found that self-efficacy correlates to transfer of learning. Furthermore, although simulation has been shown to increase the self-efficacy of nursing students, it is not well known what aspects of medical simulations are a direct result of those findings (Franklin, Burns & Lee, 2014). Gegenfurtner et al. (2014) focused on studying design features that improve self-efficacy in digital simulations based on social, narrative, adaptivity, multimedia, and assessment characteristics. They found users' ability to control the level of difficulty resulted in high levels of self-efficacy suggesting learner control is an important aspect of self-efficacy and transfer. Second, they found the timing of assessment feedback *during* or *during plus after* resulted in low self-efficacy and low transfer. Third, social characteristics, such as team presence, had no effect on self-efficacy nor did narrative characteristics, such as narrative scenarios, have any effect on self-efficacy; and adaptivity characteristics that included less complex multimedia representations had no effect on self-efficacy. Although scenario-based learning is important for other skills previously mentioned, in this analysis of the literature Gegenfurtner et al. (2014) could not find a correlation of improved self-efficacy, however, it was found the amount of control and a delay of assessment should be considered in the design to incorporate opportunities to improve self-efficacy.

Feedback

Feedback, or assessment, as defined in the previous section, is considered an effective instructional design feature in the healthcare simulation literature (Cook et al., 2013). Feedback promotes cognitive engagement and provides opportunities for the learner to engage in metacognitive activities (Cook et al., 2013). Clark and Mayer (2013) suggest both instructional feedback and intrinsic feedback should be included in the scenarios and should follow the same scaffolding design as their guidance recommendations. Instructional feedback would give the learner an immediate response to an incorrect action by telling the student what was incorrect by either voice or text, while intrinsic instruction would provide the learner with a response from the game that would let the learner see the consequence of his or her action. Examples of intrinsic feedback might include a sudden drop in heart rate or blood pressure changes for a virtual patient. Instructional feedback is inherently similar to traditional methods of assessment and, for realism; intrinsic feedback could provide the learner with a more realistic action or consequence (Ke, 2016).

Repetition and Reflection

Experiential learning theory suggests that student learning is "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience"(Kolb, 1984, p. 41). In the medical community, the theoretical framework for this transformation of experience is often carried out using the deliberate practice framework. Deliberate practice was described first by K. Anders Ericsson (2004) to define the importance of the repetitive performance of intended cognitive or psychomotor skills in a specific domain, that, when combined with rigorous skills assessment, helps develop individual skill from novice to expert.

The tenets of the deliberate practice framework include similarities to other learning strategies that intend to engage the student in developing their critical thinking skills, problem-solving skills, and metacognitive skills by engaging in repetitive and reflective practice. One tenet of deliberate practice is to engage in practice activities with the primary goal of improving a well-defined aspect of a task (Ericsson, 2015). An important aspect of both deliberate practice and mastery learning is the ability of the learner to obtain immediate expert detailed feedback as soon as the task is complete (Ericsson, 2015). Another tenet of deliberate practice is that the learner is given multiple opportunities to practice the task to progressively improve upon his or her performance (Ericsson, 2015), thus allowing the student to problem-solve to find better methods to perform the task. McGaghie et al. (2010), showed that when the tenets were applied to medical simulation, significant transfer to clinical outcomes was improved. Deliberate practice is a repetitive, reflective active activity that builds expertise through experience and problem solving and provides opportunities to build metacognitive skills through reflection of cognition. Deliberate practice has been shown to be an important framework when used in differing medical education arenas (McGaghie et al., 2010), thus implicating similar results with virtual simulations. A benefit of the virtual space, however, could decrease the amount of time and support needed in a clinical setting. According to McGaghie et al. (2010), nine characteristics of deliberate practice are used to achieve medical education goals. These may also guide the design of virtual simulations.

1. Highly motivated learners, with good concentration,
2. Engagement with a well-defined learning objective or task,
3. An appropriate level of difficulty,
4. Focused, repetitive practice,
5. Rigorous, reliable measurements,
6. Informative feedback from educational sources (e.g. simulators or teachers),
7. Monitor their learning experiences and correct strategies, errors, and levels of understanding, engage in more DP,
8. Evaluation to reach a mastery standard, and
9. Advancement to another task or unit.

Reflection can occur before the simulation in the form of planning and can continue during the simulation as the learner reflects on the results of each decision made, and after the simulation has ended. Similarly, monitoring and evaluation can also occur during or after the simulation as the leaner decides how one is doing and what is known that will help in the current, repeated, or future simulations. This type of reflection provides the learner with opportunities for improving one's metacognitive abilities. However, when Scoresby and Shelton (2014) investigated student reflection and metacognition in a 3D simulation, it was found many students were unaware of their thinking and needed a support mechanism for the reflective experience as well as guidance in learning about their metacognitive processes. This suggests prior guidance on these processes, as well as prompts and cues for reflection throughout the experience, be included.

Curriculum Integration and Perceived Usefulness

The integration of the virtual scenarios can be either formal or optional activity. There is limited research into which is more effective. McCarthy, O'Gorman, and Gormley (2015) found that medical student's use of virtual patients in microbiology courses depended largely on the student's perceptions of its usefulness for both educational and clinical attainment. Faculty integration as either formal or hidden and peer opinion had a significant impact on the perceived usefulness of the simulation activity. They also suggested they be properly positioned in the curriculum holistically and at an early stage in student learning.

McGaghie et al. (2010), reporting on all forms of medical simulations, found evidence for the integration of a simulation activity that was combined with other learning events was effective, stating that it "complements clinical education" (p.56). Likewise, integration considerations suggested by Cook and Triola (2009) included integrating the virtual patient after the delivery of core knowledge but before the standardized patient (a human patient actor). Progression would then continue to the human simulator (high fidelity mannequin), and lastly a real patient. They suggested that introducing core material first, builds the student's domain-specific knowledge from which they can begin the cognitive processes involved in working through the scenario. However, even though there was a continuum of performance in all stages, areas of competence heavily relied on each other. Hence, in a self-directed virtual simulation, it would be beneficial to include an introductory page for each scenario outlining domain-specific knowledge that would be needed for the scenario. In this way, the student could be confident in their preparedness for the activity.

Goal-based Scenario

The development of a goal-based scenario (GBS) is an approach to building scenarios that focuses on the motivation of the student to learn content knowledge through the achievement of goals. Similar to design characteristics found in scenario-based learning, Roger Schank developed this teaching strategy after noting that an important construct of motivation in learning is to provide an opportunity to achieve goals that are intrinsically motivating to the student (Schank, Fano, Bell, & Jona, 1994). Schank et al. (1994) further defined the GBS strategy as, “A GBS is a type of learn-by-doing task with very specific constraints on the selection of material to be taught, the goals the student will pursue, the environment in which the student will work, the tasks the student will perform, and the resources that are made available to the student” (p. 305). The GBS has also been described as a role-playing dynamic scenario in which the learner drives the scenario (Ip, 2002), which is similar to motivational characteristics found in online games. Likewise, Schank, Berman, and Macpherson (1999) emphasized that the relevant tasks within a scenario should be intrinsically meaningful to the student in order for the student to obtain the desired content knowledge.

The components of this strategy are similar to design suggestions from Clark and Mayer (2013) and also similar to design components of motivational games. There are seven components outlined by Schank et al. (1999).

1. Goals-There should be process knowledge goals and content knowledge goals.
2. A mission-the mission should be motivational and somewhat realistic.

3. A cover story-The background storyline should create the need for the mission. It should be motivational and it should provide opportunities for skill practice and knowledge seeking.
4. Role-The role the student dons should be an important and motivating role that will engage the student in activities that will develop the skills and knowledge outlined in the objectives.
5. Operations-There should be multiple activities which are aligned with the mission and the goals. These should include decision points and consequences that will engage the student to practice the skills outlined in the objectives.
6. Resources-Resources should be readily accessible and organized and should provide enough information to accomplish the mission.
7. Feedback-Feedback should be situated and provided just in time. This should be delivered as either a consequence, a coaching dialogue, or as a domain expert's stories about similar experiences (Schank & Cleary, 1995).

Schank and Cleary (1995) noted this strategy is well suited for the virtual environment or within the classroom. This strategy is advantageous for teaching healthcare students as it incorporates scenario-based learning in a motivational context.

Conclusion

Expertise in healthcare is desired as failure to perform may result in a catastrophic or an undesirable outcome. Providing innovative teaching practices that can keep students and professionals current in their practice and encourage a higher level of thinking have been said to be instrumental in the efforts to mitigate medical errors (Facione & Facione, 2008). For the radiology educator, there are increased challenges as expectations of radiographers to advance their roles in the healthcare team are increasing.

Even though it was found that methods to include higher thinking strategies in radiology education were needed (Kowalczyk et al., 2012), there was limited research available for specific teaching strategies for the profession. Thus, it was necessary to survey the literature to examine innovative teaching strategies found in other healthcare professions. Based on recommendations made by researchers and governing agencies, a review of current simulation research, scenario-based learning research, and design features of educational virtual environments was performed.

Simulation research was found to be widely diverse, however, many researchers agreed educational value from simulation activities was improved or least the same as traditional instructional methods (Cheng et al., 2014; Cook et al., 2012; Ilgen et al., 2013; Ma et al., 2011; McGaghie et al., 2011). Researchers also agreed that foundations in domain-specific knowledge were important (Brown et al., 1989; Clark & Mayer, 2013; Ke, 2016), however, recalling information with efficiency and accuracy, in a situated context imbues a higher level of thinking which cannot be strengthened through contextual learning alone (Brown et al., 1989; Izaute & Bacon, 2016).

As a higher level of thinking is proposed for radiology students in advanced modality courses, a review of scenario-based learning was also explored. Researchers agreed scenario-based learning in the form of problem-based or case-based scenarios revealed positive effects for healthcare students (Cook et al., 2010; Jamkar et al., 2007; Neufeld & Barrows, 1974). It was also found that scenario-based learning appeared to be better achieved embedded in a virtual environment (Benedict et al., 2013; Clark &

Mayer, 2013; Gavgani et al., 2015). Some benefits reported were less reliance on faculty, less time spent in the laboratory, reduction in required space, and customizable scenarios for individuals in level of difficulty and variability. Virtual applications also provided multiple opportunities for guided feedback and instruction, had the ability to be repeatable, provided an opportunity for reflection, and were said to contribute to transfer of knowledge to clinical practice by allowing the student to make mistakes safely with the ability to review realistic consequences.

As a result of this review, this study was built on simulation and scenario-based learning research by exploring the effects of a virtual scenario-based simulation activity in advanced modality imaging courses.

CHAPTER THREE: METHODOLOGY

This chapter presents the research design, participants, instructional intervention, data collection, data analysis, assumptions, and limitations of the study. The goal of this study was to investigate the impact of the integration of a virtual branching scenario-based simulation activity as an online formative activity in advanced imaging courses for undergraduate radiology students. This study also aimed to provide guidance on the design and implementation of virtual scenario-based simulations.

The impetus for this study was a response to the continued safety movement for medical mistakes and as a response to growing expectations and responsibilities of the radiographer (ACICBL, 2011; IOM, 1999; IOM, 2003; Martino & Odle, 2008; Ziv et al., 2003). To mitigate errors in healthcare, it has been suggested that educators look for innovative teaching strategies that will imbue strong critical thinking and problem-solving abilities of the radiology student, and that will guide future providers to become life-long learners (ACICBL, 2011; IOM, 2003; Martino & Odle, 2008; Ziv et al., 2003). Educational technologies, such as scenarios and simulations, were suggested by many organizations and researchers as a way to accomplish this task (ACICBL, 2011; IOM, 2003; Martino & Odle, 2008; Ziv et al., 2003).

Although the introduction of online education in the radiology profession broadens the reach for needed advanced education, radiology education programs need ways to improve the level of learning in online courses in advanced radiology modalities.

The problem in this study relates to the exploration of innovative teaching methods that will aid in current and future demands in radiology.

Combining the best practices of scenarios and simulations in a virtual environment has been seen in other healthcare professions, thus this mixed methods case study aimed to contribute to the limited research on the use of virtual scenario-based simulations to enhance the learning experiences of online radiology students.

Research Questions

There were two research questions guiding this study.

1. For the group of advanced imaging radiology students in this case study, how does the design of the virtual scenario-based branching simulation impact the students' satisfaction with the learning experience?
2. For the group of advanced imaging radiology students in this case study, how does a virtual scenario-based branching simulation impact the students' confidences in their ability to make appropriate decisions in real-world practice?

Research Design

Mixed Methods Case Study Design

The design of this study was a mixed methods case study following a concurrent design. The focus of a case study as described by Creswell (2013) provides an in-depth description and analysis of a case and allows the researcher to study multiple individuals and the activity in which the researcher will be engaged. Case study has been used extensively in educational innovations (Merriam, 2009). Yin (2009) defined the case study as, "An empirical inquiry about a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p.18). This case study took place in a real-life setting within the boundaries of an online course and was bounded in time (one semester, which is approximately four months) and place (one department at one university). It covered a broad range of contextual and other complex conditions involving both instructional design and educational theories for a particularly unique population in which there was no clear single set of outcomes. This type of case study is described as an exploratory design by Yin (2003), and according to Merriam (2009), a heuristic design with unknowns that will be illuminated as the study emerges should rely on inductive reasoning (Merriam, 2009). The study will explore the phenomenon for context and behavior in an attempt to provide a complete "thick" (Merriam, 2009, p. 166) description of it and its meanings.

A common argument against case study is that generalization of results may be limited since the study is focusing on one group. However, Yin (2012) stated that the purpose of a case study is not to produce statistical generalizations and that case study generalizations should be viewed from an analytic perspective rather than statistical grounds. Generalizations to other situations instead of generalizations to populations are sought. It is the goal of this study to make generalizations based on transferability to a similar population, radiology students in advanced imaging courses, as opposed to the general population.

Extended research would be needed to effectively generalize the findings among other imaging courses outside of the confines of this study. Since this mixed methods case study aims to contribute to the limited amount of literature on this subject, the results may inform any subsequent quantitative research that could produce more statistical generalizations.

In an effort to provide a better understanding of the research problem a mixed methods approach, which incorporates both qualitative and quantitative research data, was used (Creswell, 2013; Johnson, Onwuegbuzie, & Turner, 2007). Definitions of mixed method design are many and in an analysis of mixed methods definitions by Johnson et al. (2007) a concise definition was surmised.

> Mixed methods research is an intellectual and practical synthesis based on qualitative and quantitative research; it is the third methodological or research paradigm (along with qualitative and quantitative research). It recognizes the importance of traditional quantitative and qualitative research but also offers a powerful third paradigm choice that often will provide the most informative, complete, balanced, and useful research results (p. 129).

The appropriateness of a mixed methods approach for this case study stemmed from the need for an in-depth and pragmatic exploration of the particular research questions. The lack of current research of the virtual scenario-based simulation innovation in the field of radiology was better understood by exploring both quantitative and qualitative aspects of the phenomena.

Benefits of this design are its ability to overcome weaknesses of qualitative and quantitative methods by building meaning from the strengths of the other, such as adding context of meaning to numerical data through words and by providing opportunities for triangulation as it can provide multiple perspectives of the research problem adding insight to meaning.

As described by Creswell and Plano-Clark (2011), this was done by collecting and analyzing both types of data and by integrating the data using a concurrent design. Both qualitative and quantitative data were collected at the same time (Figure 1).

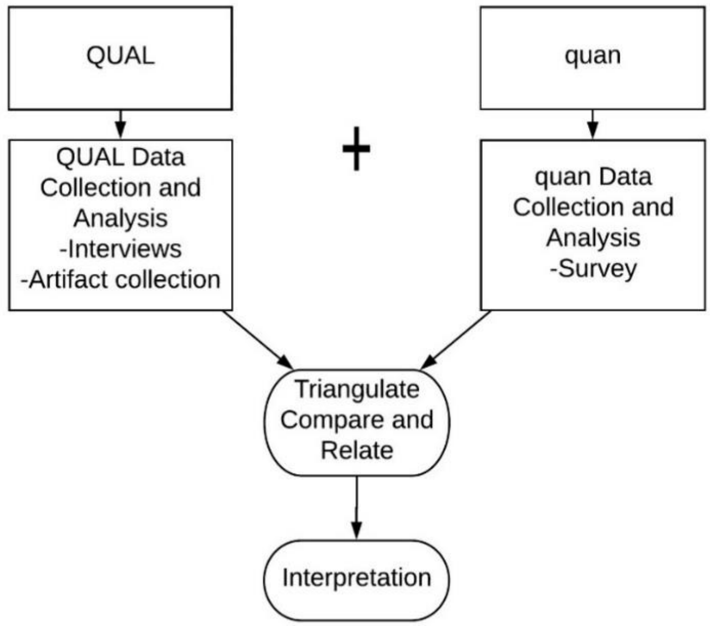

Figure 1. Mixed Methods Concurrent Design. This figure illustrates data collection, triangulation, and interpretation of mixed methods concurrent design.

Historically medical imaging and the healthcare profession has been dominated by quantitative research designs as factual and reliable outcome data are desired for delivering reproducible life-saving techniques and treatments (Munn, Porritt, Lockwood, Aromataris, & Pearson, 2014). Similarly, in the education of the healthcare student it is has been standard to assess students on a summative level to reproduce domain-specific knowledge which is measured through quantitative methods and standardized tests (Wing, Koster, & Haan, 2014). However, educating healthcare professionals requires complex human interactions that are not always easy to explain. A detailed search for qualitative research in radiography education revealed an increasing presence of the use of qualitative measures (Aura et al., 2016; Fowler & Wilford, 2016; Goldin, Narciss, Foltz, & Bauer 2017; Perram et al., 2016). For this study, a look at the experiences of the radiology students was needed in an effort to gain insight into how each student interprets meaning from an innovative educational strategy. This was guided by the notion that application of learned knowledge in context is affected by the individual student's perceived self-confidence, his or her perceived usefulness of the learning activity (Knowles, Holton, & Swanson, 1998; Thomas, 2007; Gegenfurtner et al., 2014), and his or her opportunity to problem-solve within the learning experience (Knowles et al., 1998; McGaghie et al., 2010).

As described by Creswell (2013), the qualitative methodology provides a rich and in-depth understanding of a process or phenomenon (Creswell, 2013). This mixed methods case study was aimed at understanding the phenomenon by discovery and through the identification and characterization of important categories and dimensions in the phenomenon (Creswell, 2013) within a natural setting. The study was also intended to invoke complex reasoning through inductive methods (Creswell, 2013).

As the innovative teaching strategy had not fully been explored in the education of the specific population of students in this study, and since this study is complex, the addition of the qualitative method lent well to the exploration of student interactions with the virtual scenario-based activity. However, the unique attributes of the study required a more specific case study design.

The quantitative data evaluated design aspects of the virtual simulation that affected student satisfaction and student self-confidence. The qualitative portion of this study intended to give the study more depth by providing insight into the results of the quantitative data. The mixed methods design allowed for a contrasting look at the practicality of the innovation. Furthermore, Johnson et al. (2007) concluded that a mixed methods design is likely to provide superior research findings and outcomes when there is "…a nexus of contingencies in a situation, in relation to one's research question(s)" (p.129). The nexus in this study surrounds the variances in human perceptions and the reactions to those perceptions, while also investigating the innovative educational technology tool.

Participants

Sample Selection and Setting

The sampling technique is purposive sampling. A purposive sample is a non-probability sample that is selected based on the characteristics of a population and the objective of the study. The characteristics and objective of this case study required a selection of students enrolled in advanced imaging courses in magnetic resonance imaging (MRI) and computed tomography (CT). Therefore, the student population selected were undergraduate radiologic sciences students enrolled in these advanced imaging courses.

The total population of students enrolled in the courses was invited to participate in the study (N=57). The expected selection of students for interviews was a simple random sample of n=15 as it was desired to obtain perspectives from all levels and backgrounds of students enrolled in the courses. Regarding the number of interviewees chosen, there were many suggestions in the literature for the level at which saturation occurs, which was anywhere from 5-60 (Creswell & Plano-Clark, 2011; Gentles, Charles, Ploeg, & McKibbon, 2015). Yin (2009) noted that due to the nature of the case study approach that the typical criteria regarding the sample size was irrelevant. He noted that the number of participants or cases should be a reflection of the replications to gain information about various aspects of the case. So it was decided an initial representation that was also manageable was 15. During the data collection process, it was found that saturation occurred for this group of participants at the sixth interview.

The advanced imaging courses chosen for this study were fully online MRI and CT courses. MRI is a radiology modality that has severe consequences for patients and providers if protocols and safety measures are not followed (Watson, 2015). Fatalities and life-altering instances have occurred within this modality (Watson, 2015). The hazards involve the technology itself (projectiles, external burns, internal burns, displacement of implanted devices, acoustic damage, asphyxiation), protocols (delay of care, misdiagnosis), and contrast media (anaphylaxis, Nephrogenic Systemic Fibrosis, extravasation) (Kanal et al., 2013), CT has similar hazards and consequences involving the technology (radiation exposure, equipment weight limitations, power injectors), protocols (delay of care, misdiagnosis), and contrast media (anaphylaxis, contrast-induced nephropathy, extravasation) (ASRT, 2017b; American College of Radiology [ACR], 2017). These modalities are also unique in that each patient requires an individualized screening process and protocol regimen based on past medical history, disease pathology, and history of present illness (ASRT, 2017a; ASRT, 2017b). Ultimately, the technologist is responsible for making many different decisions about each patient. This provided the researcher with a number of options to include an individualized path for each student based on the choices the student made, thereby challenging the students’ decision-making abilities.

This setting lends well to the virtual scenario-based branching strategy. The courses were also chosen because they are delivered entirely online at this university. The goal to include realistic individualized activities for the online environment is especially important in advanced modality courses in which the students are learning vital concepts at a distance.

Additionally, the current designs of the courses were in need of realistic interactive components. Currently, the only interaction in the courses is an assignment in which students visit an advanced imaging suite and complete a series of observations of predetermined exam types in which they observe the protocols and safety measures required when in the environment. However, because of safety concerns, MRI students are not actual participants within the environment and are only allowed to be bystanders, and, even though students in the CT course are more likely to interact in a CT observation, access to CT is not always granted. It is common students who enroll in these courses do not have any access to an MRI suite or a CT suite in any capacity. For these students, an alternative paper-based assignment is usually provided that aims to include the same objectives as the actual observation. The paper-based assignment is not interactive and does not challenge the decision-making skills of the student.

Both advanced imaging courses are similar modalities and were developed in the same manner by the same designer providing a near-identical online course structure. This provided consistency for the design and implementation of the simulations.

Instructional Intervention Design

Virtual scenario-based simulations are currently underdeveloped for radiologic science curriculum so virtual scenario-based simulations were designed and developed to be used within the specific context of two advanced modality courses at this university. The design of the product used for this study was based on simulation and scenario-based learning in healthcare with the underpinnings of instructional design characteristics set forth by educational e-learning scenario-based research strategies found in the literature. Each design characteristic was chosen with the purpose of providing the student an opportunity to become situated within the context in order to improve their satisfaction in learning and to provide an opportunity to build confidence in applying classroom learning to clinical practice to achieve valued goals within a semi-realistic safe environment. An overview of the scenario-based simulation design is provided in this chapter and examples of the instructional design documents, screenshots, and a video walk-through are provided in the appendices.

The build of the scenario-based simulation first required a search for e-authoring software that met the needs for the design. E-learning authoring software was investigated with design considerations for interaction with current artifacts and documents, branching ability, online and offline publication ability, integration with the university's learning management system (LMS), and ease of use for faculty. The software used was Articulate 360.

The specific design characteristics chosen from the literature search included careful consideration for curriculum integration, task deliverables, scenario resources specific to the scenario-based simulation, and a trigger event. It incorporated goal-based design characteristics that provide motivation that included goals, a mission, a story, and the student's role within the story. There were multiple problem-solving opportunities, multiple opportunities for guidance and instruction that were presented in a scaffolding design, immediate feedback including instructional, intrinsic and supporting responses. A branching design was incorporated with multiple opportunities for repetition and reflection, autonomy, and delayed assessment. To measure satisfaction with the design, and satisfaction and confidence in learning each characteristic was aligned with the specific subcategories of the Simulation Design Scale survey and the Student Satisfaction and Self-confidence in Learning survey (Table 4).

Table 4 Alignment of Survey Instruments with the Design Characteristics

Design characteristics included in the scenario-based simulation	Simulation Design Survey Subcategory	Questions	Satisfaction & Confidence Survey Subcategory	Questions
1. Curriculum integration & Instructions for Pre-Learning	Objectives & Information	1-5		
2. Task deliverables	Objectives & Information	1-5		
3. Scenario resources	Objectives & Information	1-5		
4. Trigger event (*why this is important*)	Realism	19-20	Satisfaction	1-5
5. Goals, Mission, Story, Role	Objectives & Information Realism	1-5 19-20	Satisfaction	1-5
6. Problem-solving (*identify & analyze problems, use resources to attempt a solution, appraise outcome of solution*)	Problem-solving	10-14		
7. Guidance & Instruction (navigation, resources, scaffold design)	Objectives & Information Support	1-5 4-9	Satisfaction	1-5
8. Feedback (immediate, instructional & intrinsic-branching tips)	Feedback & Guided Reflection Realism	15-20 19-20	Satisfaction Confidence	1-5 6-13
9. Branching Design			Satisfaction	1-5

Design characteristics included in the scenario-based simulation	Simulation Design Survey Subcategory	Questions	Satisfaction & Confidence Survey Subcategory	Questions
10. Repetition (*unlimited*) & Reflection (*pre-planning, during, & post reflection*)	Feedback and Guided Reflection	15-20	Confidence	6-13
11. Self-efficacy & transfer (*autonomy, delay of assessment, no social aspect)*			Confidence	6-13
12. Assessment (*participation, worksheet with reflections*)			Confidence	6-13

To provide a realistic environment the student was tasked with applying multiple components of previously learned information in the virtual environment in order to function as a technologist with each virtual patient, just as they would with actual patients. Each student worked through four scenarios that were interconnected in a chronological design.

To account for careful curriculum integration, each scenario was adjusted to engage the student with objectives learned in the first several course modules of the online course (Figure 2). The presentation of the scenarios was simple in the beginning and became more complex as the student progressed.

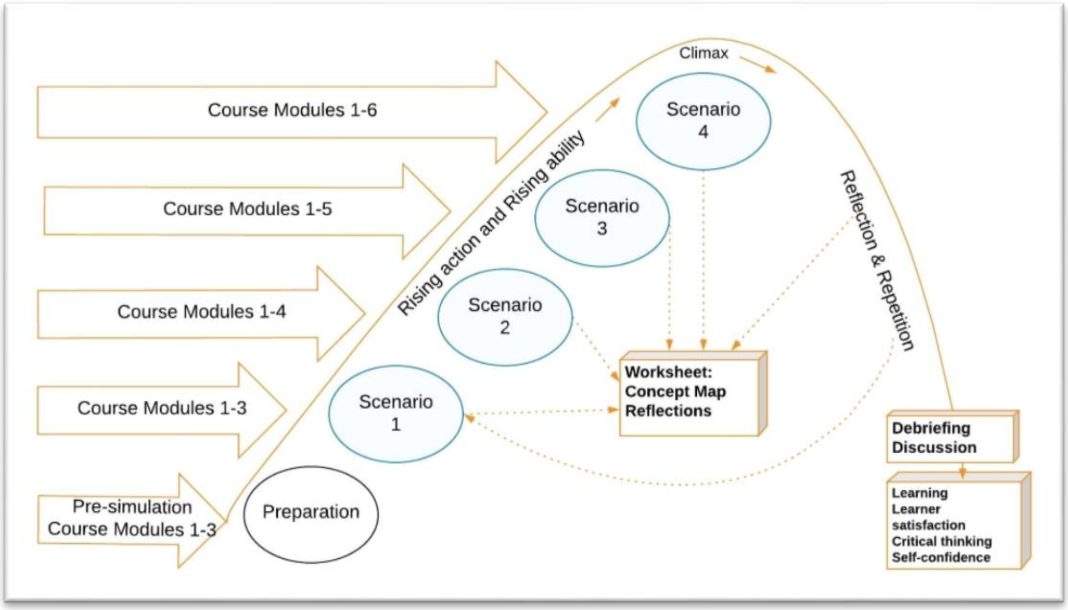

Figure 2. Simulation instructional map. This figure illustrates implementation design.

The scenarios begin with clearly defined task deliverables and scenario resources. As suggested by Clark and Mayer (2013), this includes the desired actions and decisions that will reflect critical thinking skills, the paths that would be determined to define successful or moderate completion, procedural skills that may need to be completed in a particular order, and domain-specific knowledge that may need to be known prior to the learner's engagement with the activity (Clark & Mayer, 2013). The learner was provided with both the objectives and the resources needed to be successful within the environment.

The student was then provided with a trigger event to incite a sense of urgency. Each scenario day begins with a "Why is this important?" scene in which a catastrophic event that has actually occurred in real life is provided that is related to the scenario. An example was an event in which an oxygen tank was inadvertently brought into an MRI suite while a 6-year boy was in the MRI bore. The tank was propelled into the magnet killing the young boy. The goal for the learner was to avoid this type of catastrophic event in their own virtual experience.

Following the guidance of several researchers (Clark & Mayer, 2013; Gordon, 2009; Salas et al., 2005; Schank et al., 1999), the scenarios were then presented in a storyline format in which the student portrayed the role of a new advanced imaging technologist that was filling in at a satellite facility in which the character was not accustomed. The mission was to become adjusted to the facility quickly and safely and to successfully care for patients and coworkers with no incidents or sentinel events. The student accessed the scenario-based simulations within the learning management system for the respective courses. Once a simulation was accessed, the student proceeded through each day engaging with other virtual characters (patients and coworkers) and engaging with obstacles, hazards, critical pathology, technological considerations, and ethical situations in which the student made decisions that affected how the patients and providers responded thus engaging the student in multiple problem-solving activities.

As suggested in the literature, the amount of guidance and availability of resources the student has access to within the scenario was incorporated following a scaffolding framework. Increased guidance and resources were available for the student in the first simulated day with minimal consequences for incorrect decisions. Guidance was decreased each day as difficulty and consequences increased. By day four, the student had little guidance and the consequences became catastrophic.

Feedback within the scenario was designed as both instructional and intrinsic. As suggested by many researchers, feedback was provided immediately in the form of a consequence, a coaching dialogue, or as a domain expert's story about similar experiences (Clark and Mayer 2013; Cook et al., 2010; McGaghie et al., 2010; Okuda et al., 2009; Schank & Cleary, 1995). An example of an intrinsic consequence in the scenario is the choice of the student to enter the MRI suite with a pair of ferrous scissors. If the student chose to enter (incorrect decision), the scissors were jerked from his or her hand by the force of the magnet causing another technologist in the room to become impaled by the scissors. An example of instructional feedback is with critical pathology identification, in which the student chose the critical pathology seen in the CT image for his or her patient. An example is a hemorrhagic brain bleed for Mr. Dement (the virtual patient). If the student identified the pathology incorrectly a pop-up appeared that instructed the student that their choice may cause a delay of care and they should revisit their notes to try to quickly and correctly identify the pathology before moving forward. They were presented with the notion that Mr. Dement was counting on the student to identify any critical pathology so the radiologist can view the scan as quickly as possible. The notes the student may have to refer to in these situations may be provided in a tip button. These tip buttons were included occasionally throughout the scenarios to provide coaching feedback about difficult concepts if the student needed immediate help (Clark & Mayer, 2013). The tips were also introduced using a scaffolding framework. There were more at the beginning of the scenarios and less in the end. The choice of feedback design was selected to provide the learner with a more realistic component, which was suggested to increases motivation (Clark & Mayer, 2013; Ke, 2016), thus increasing the likelihood of increased learner satisfaction.

The branching design was chosen to provide a realistic component and to individualize each student experience. As the student begins to experience less guidance and more catastrophic consequences the scenario can change based on the student's decisions. As suggested in the literature a branched design is ideal for learning critical concepts. This design is ideal for including problem-solving scenarios that encourage the critical thinking and decision making skills of the learner (Gordon, 2009; Smith et al., 2014; Talbot et al., 2012). Additionally, another motivation for the inclusion of the branched design is this design is similar to components of serious games which have been said to increase motivation (Kapp, 2012),. The complexity of the branching in this scenario was determined by the level of scaffolding within the scene, the objectives for the scene itself, and the number of support items associated with the scene. No more than three different branches were designed for each decision point. There were several ways in which the scene branched to additional scenes. The student decision could lead to an instructional slide in which the student is told their choice is not the best answer and why. These slides led to supporting material the student could use to go back and try again. More complex branching involved a consequence to the patient or provider. After the consequence, some of these would ask the learner to review instructional material and try again, however, there were some of these that required the student to react to what was going on based on their decision. They would then have to branch to additional scenes to further problem-solve the situation. An example would be when the patient would suddenly collapse as a result of their choice; the student would then have to choose to perform CPR to save the patient's life and they would have to perform CPR in a given time frame. A few snapshots of one of the scenes are provided in Appendix A, and a short video of one of the scenes is provided in Appendix B.

The design also allows for repetitive practice of all components of the scenario with no penalties for exploring incorrect decisions, which is a major tenet of the deliberate practice framework. In addition, providing the students with control was suggested in the literature to be an important aspect of self-efficacy and transfer. Since self-efficacy is positively related to confidence (Pajares, 1997) it can be surmised this will improve the student's confidence.

The use of delayed assessment was used as it was noted by Gegenfurtner et al. (2014) that assessment during the simulation resulted in low self-efficacy and transfer. The assessment comes from the completion of a predetermined number of scenes (70 %) and completion of the associated worksheet that is filled out as the student proceeds through the scenario (Appendix C). The worksheet includes opportunities for the student to organize, document, and reflect on his or her learning strategies in addition to reflecting on his or her experience as a whole. Reflection is another of the major tenets of the deliberate practice framework.

Additionally, in a virtual environment the level of realism can become complex, so for simplicity and as an attempt to reduce cognitive demands on the learner, the design for this study focused on the content and on only one form of delivery which was visual. The CT and MRI images, the pathology images, and the background images were real, however, the dialogue remained in a text form rather than auditory or through a video. To recount, the level of realism in the design of this virtual scenario-based simulation was founded on both simulation and scenario-based design suggestions. Reedy (2015) suggested that high-fidelity simulations incorporate higher levels of realism and complexity as students progressed in their learning (scaffolding). Likewise, scenario-based learning was based on the principles of situated cognition, therefore Clark and Mayer (2013) suggested virtual scenarios be designed to be as realistic as possible. Salas et al. (2005), also indicated that for high-risk environments content-valid realistic scenarios were critical. Notably, though, while insisting that the design be realistic there were no clear boundaries for the level of realism in simulation and scenario-based research.

Design documents were developed for the organization of the instructional design. These were a preliminary design document, an instructional design outline, and an individual spreadsheet for each scenario day. The preliminary plan document included a summary and a front-end analysis that defined the problem, context, learner analysis, relevant standards, learning activity goal and outcomes, a brief outline of the design, and formative evaluation (Appendix D). The second design document was an outline that mapped the entire activity. It included objectives, planning, and the script for all of the scenarios for the course (Appendix E). The third document was a spreadsheet that divided the scenarios by the patients and mapped the scenario plan (Appendix F).

Peer reviews

Content experts were beneficial for this particular study. The primary content expert was a radiology professional who has a background in clinical and didactic instruction in radiologic sciences and biomedical engineering, and who has over thirty years' experience in the field. He was asked to review the virtual scenario-based simulations during the planning and development stages and then again before implementation. Two other content experts were asked to review the virtual scenario-based simulations. One was an expert in MRI and a professor in radiologic sciences at

MSU who was asked to review the MRI simulation. The other was a content expert in CT and a professor at MSU in radiologic sciences who was asked to review the CT simulation. Another content expert in educational technology, who is a graduate professor at Boise State University, reviewed the instructional design of the MRI simulation in the planning and development stages.

Data Collection

Data collection instruments used in this study included artifacts in the form of worksheets from the virtual assignment, semi-structured interviews, and a survey.

Worksheet Assignment

The worksheet assignment measured the student's decision-making abilities through identifying correct protocols, describing individual learning opportunities, describing standard and non-standard procedures, and identifying internal and external safety hazards in the MRI or CT environment. The worksheet also required the student to reflect on his or her perceived learning and his or her personal experience in the virtual activity for each scenario 'day'.

Semi-structured Interviews

The interviews were semi-structured with a structured demographic component included. Questions were semi-structured, open-ended questions delivered in a conversational style (Appendix G). A storied approach was used (Ellis, 2010). Although initial questions were designed to elicit anecdotes and stories, not all questions were fully developed prior to the interviews, allowing the interviews to evolve. This allowed a comparison of the participant with others and provided insight into the participant's unique experiences. The interviews varied in length from 30-45 minutes. No students were able to meet in-person as they all lived at a distance. These were conducted by phone and video conferencing. Each interview was audio-recorded and transcriptions were made. Interviews were conducted during the intended semester.

Survey

The two survey scales provided data on simulation design, satisfaction, and self-confidence (Appendix H). The two scales were combined and entered into SurveyMonkey® as one survey for the students to complete online. The surveys have been developed and validated by the National League of Nursing (NLN), and are the Simulation Design Scale (Student Version) and the Student Satisfaction and Self-Confidence in Learning. Both scales have been widely used in simulation research since 2006 and were reevaluated in 2014 adding robustness to their validity and reliability (Franklin et al., 2014). The purpose of the survey in this study was to explore students' perceptions of virtual scenario-based simulation as a learning strategy.

The Simulation Design Scale (Student Version). This is a 20-item instrument using a five-point scale. Originally designed to evaluate the five design features of the instructor developed simulations used in the NLN/Laerdal study (Jeffries & Rizzolo, 2006), the instrument was used in this study to evaluate the virtual simulation design in this study.

The design features include: 1) objectives/information 2) support 3) problem solving 4) feedback and 5) fidelity. The instrument has two parts: one asks about the presence of specific features in the simulation, the other asks about the importance of those features to the learner. Content validity was established by ten content experts in simulation development and testing. The instrument's reliability was tested using

Cronbach's alpha, which was found to be 0.92 for the presence of features, and 0.96 for the importance of features (Jeffries & Rizzolo, 2006, p. 6).

Student Satisfaction with Learning Scale. This is a 5-item instrument designed to measure student satisfaction with five different items related to the simulation activity. Content validity of the instrument was established by nine clinical experts validating the content and relevance of each item for the concept of satisfaction. Reliability was tested using Cronbach's alpha and found to be 0.94 (Jeffries & Rizzolo, 2006, p. 6).

Self-Confidence in Learning Scale. This is an 8-item instrument measuring how confident students felt about the skills they practiced and their knowledge about caring for the type of patient presented in the simulation. Content validity was established by nine clinical experts in nursing, and reliability was tested using Cronbach's alpha which was found to be 0.87 (Jeffries & Rizzolo, 2006, p. 6).

For the Student Satisfaction and Self-Confidence in Learning Scale, scores are obtained by adding responses to all items, with a maximum total of 65. Higher scores denote higher levels of satisfaction and self-confidence.

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Data Analysis

All recorded information was entered into a secure computer file, and students were assigned a code that was used in place of their name to ensure anonymity was maintained. The dataset included demographics, quantitative data, and qualitative data. The demographics included age, gender, time in the profession, time in the modality, simulation experience, scenario experience, which program (course) they were in, and confidence with virtual technology.

Quantitative Data Analysis

The results from 57 quantitative surveys were gathered and entered into Statistical Package for the Social Sciences (SPSS). The survey scales ranged from 1 to 5 [1 =

Strongly Disagree (SD), 2 = Disagree (D), 3 = Undecided (UN) (neither agree nor disagree), 4 = Agree (A), 5 = Strongly Agree (SA)]. The Simulation Design Scale had an additional measurement of importance regarding each statement which was also measured on a scale of 1 to 5 (1=Not Important, 2=Somewhat Important, 3=Neutral, 4=Important, 5=Very Important). Results from the surveys were presented using descriptive statistics and were demonstrated according to the representative sub-sections within the surveys. The survey subsections of the Student Satisfaction and Self-Confidence in Learning scale included Student Satisfaction with Current Learning (Table 7), and Self-Confidence in Learning (Table 18). The survey sub-sections of the Simulation Design Scale included Objectives and Information (Table 8), Fidelity (Realism) (Table 14), Support and Feedback (Table 10), and Problem Solving (Table 12).

Descriptive statistics using measures of frequency were used to analyze the data. It is suggested for Likert–type items nonparametric tests are more appropriate statistical measures when measuring a series of Likert-type questions, as compared to Likert-scale questions. In this study, the survey items are more closely represented as ordinal data rather than interval data. Even though the questions are grouped into categories, according to Boone and Boone (2012), "If your Likert questions are unique and stand-alone, then analyze them as Likert-type items. Modes, medians, and frequencies are the appropriate statistical tools to use." (p. 4).

For the research question, "For the group of advanced imaging radiology students in this case study, how does the design of the virtual scenario-based branching simulation impact the students' satisfaction with the learning experience?" calculations were made for the frequencies, the medians, and interquartile range scores for each of the Simulation

Design Scale instrument's five subscale questions and for the Student Satisfaction with Learning Scale questions.

For the research question, "For the group of advanced imaging radiology students in this case study, how does a virtual scenario-based branching simulation impact the students' confidences in their ability to make appropriate decisions in real-world practice?" calculations were made for the frequencies, the medians, and interquartile range scores for each of the eight items of the Self-confidence in Learning Using Simulations Scale questions.

Qualitative Data Analysis

The qualitative data components were gathered, prepared, and then entered into NVivo 12© CADAQS software to be organized and analyzed through the process of coding. Coding permitted consolidation of the meaning of the data to develop an explanation of the phenomena into general themes (Saldaña, 2016).

The pre-coding process began with analytic memoing by the researcher during the collection of the student worksheet data and from the semi-structured interview data. This pre-coding strategy provided an opportunity to concurrently reflect on coding processes and code choices to be used. Analytic memos are a qualitative data collection method in which the researcher concurrently reflects and writes about the process of inquiry as it emerges (Saldaña, 2016). Saldaña (2016) indicated analytic memos provide an opportunity for the documentation of emergent patterns, categories and subcategories, themes, and concepts that may evoke a deeper understanding of the phenomenon. Additionally, other researchers suggested that memoing enhances the quality of qualitative research by providing momentum and by preserving thoughts and ideas that transpire during the data collection process that may later prove significant (Birks, Chapman, & Francis, 2008; Polit, Beck & Hungler, 2006).

For the interview data, memoing occurred during the interviews and again during the transcription process. After each interview was concluded the audio file was transcribed verbatim by the researcher so that memoing and transcription could be done simultaneously. This allowed the researcher to continue to review and reflect on the data after each interview preserving any thoughts that transpired from each interview. The choice of the researcher to transcribe the data personally, as opposed to outsourcing to an automatic or paid transcription service, not only provided an opportunity for immediate memoing, it also provided a way to maintain data quality (Witcher, 2010). Data quality was a primary concern as the verbiage used within a medical context is often unique to healthcare professionals. Similar to transcribing in another language, specific meanings of the terminology, lingo, colloquialisms, expressions, and references may be lost to an outsourced transcription service. A true understanding of the dialogue without misinterpretation was essential in this case study.

The use of memoing continued with an initial appraisal of the student worksheet data. From the memos, it was confirmed that most of the interview and worksheet data could be included in at least one of three categories outlined in prior research and in the student surveys. As such, three initial code sets were developed that represented 1) each design strategy; 2); each description of confidence; and 3) satisfaction elements not outlined in the design strategies.

Once the transcriptions and initial reviews were completed, the interview data and worksheet data were entered into NVivo 12© for coding. As the first-cycle coding progressed and in vivo coding took place, additional nodes evolved and were added to these categories as the researcher began to further understand the data. In vivo coding is a first cycle coding method also known as “verbatim coding” (Saldaña, 2016) in which the actual spoken words of the participants are used for coding. Placing the emphasis on the participants’ words rather than developing a list of predetermined words is a strategy that, according to Stringer (2014), “...[is] more likely to capture the meanings inherent to the people’s experience” (p. 140), A thorough understanding of the participant’s perceptions about their experiences with the virtual scenario is the basis for this study.

Second cycle coding was then performed allowing themes to emerge from the already coded data. According to Saldaña (2016), second cycle coding is an advanced method of reorganizing and renaming the already coded data to develop more select groups of categories, themes, and theories. One type of second-cycle coding, focused coding, was used to provide categorization of the already coded data based on thematic or conceptual similarity (Saldaña, 2016). The most salient categories were derived from the most frequent or most significant codes discovered from the first cycle coding (Saldaña, 2016). A codebook was developed to organize and understand the codes, to define the codes, and to provide an opportunity to reorganize when needed (Saldaña, 2016) (Appendix I). Once coding was completed the results from all data were compiled according to the research questions.

Conclusions through triangulation were performed with multiple sources of data. The connections found between categories and themes were used to inform the research and understanding of the radiology students’ experiences with and perceptions of virtual scenario-based branching simulations. The design of the study focuses on satisfaction with the learning experience and confidence in the student's ability to make appropriate decisions in real-world practice. All of the quantitative and qualitative data collection instruments address these questions. As a result, merging data analysis in this concurrent mixed methods case study approach is presented as a side-by-side comparison in the results and discussion sections (Creswell & Plano-Clark, 2011) with a focus on providing a holistic understanding of the phenomenon. Although the analysis was dependent upon the findings, the strategy for comparing the results was that significant quantitative findings were presented with supporting qualitative findings.

Research Quality

A limitation of qualitative research, in general, is related to validity and reliability. Qualitative research is often criticized as lacking in credibility and robustness, and, as such, has been seen as inferior to quantitative research and other methods (Leung, 2015). As validity and reliability are more quantitatively oriented, Lincoln and Guba (1986) described four alternative criteria to provide soundness in qualitative research. They proposed that internal validity be discussed in terms of credibility, external validity in terms of transferability, reliability in terms of dependability, and objectivity in terms of confirmability.

Creswell and Miller (2000) suggest the researcher of a qualitative account demonstrate credibility has been established through several validity procedures. Some common procedures that were adopted for this study include the research design, organization, member checking, triangulation, thick description, and reflexivity (Creswell, 2013; Leung, 2015; Lincoln & Guba, 1985; Merriam, 1998; Merriam, 2009).

Research Design

In addition to the common procedures used to establish credibility, the case study design for this mixed methods case study also helped to mitigate credibility concerns. Credibility was easily established as a unique attribute of a qualitative case study design through the inherent use of multiple data sources (Creswell, 2013; Patton, 1990; Yin, 2003), which may include, but are not limited to, interviews, observations, artifacts, focus groups, and even quantitative survey data to provide a holistic understanding of a phenomena (Baxter & Jack, 2008). It was reported that convergence of the data enhances the quality of the data and confirms the results (Baxter & Jack, 2008). Baxter and Jack (2008) describe this unique collection of data as, "Each data source is one piece of the "puzzle," with each piece contributing to the researcher's understanding of the whole phenomenon. This convergence adds strength to the findings as the various strands of data are braided together to promote a greater understanding of the case" (p. 554).

Mixed Methods

To enhance the quality of the qualitative portion of this case study, the use of a mixed methods approach was performed. As previously described, collecting and analyzing both quantitative and qualitative types of data and by integrating the data this design addresses weaknesses of traditional qualitative and quantitative methods. Supporting the quantitative data through the qualitative component provided depth and meaning to the numerical data through words. The mixed methods case study approach allowed for triangulation and provided multiple perspectives of the research problem adding insight to meaning.

Organization

Although using multiple data sources established credibility, retaining reliability required the researcher to effectively organize the data (Creswell, 2013; Yin, 2003). The use of qualitative data collection software was used in this study to maintain organization and to provide an emergence of themes among the data. In addition to the organization of the data, the inquiry process was documented by recording the process of the research steps from the beginning of the research to the reporting of findings improving transparency and confirmability.

Member Checking

The member checking method is considered an important step in establishing credibility in qualitative research (Creswell, 2013; Lincoln & Guba, 1985; Stake, 1995). The researcher involves the participants and brings the data, the interpretations, and conclusions back to the participants so they can confirm the narrative is accurate and the information is correct (Creswell & Miller 2000).

Triangulation

A convergence of multiple sources of information to form themes or categories is a validity procedure that has been used by many researchers to corroborate evidence (Creswell, 2013; Lincoln & Guba, 1985; Stake, 1995). Denzin (1978) described that no measurement is free from flaws; therefore, he suggested triangulation could be used to validate consistency of findings, and, in addition, any divergence may elucidate areas in need of further evaluation. (Denzin, 1978).

The use of two or more research methods was described by Denzin (1978) as methodological triangulation, as opposed to theoretical, data, or investigator triangulation. Methodical triangulation was used for this study. The data collection methods intended to provide a complete description of the experience. Each piece contributed additional information by providing different angles through time and through reflection. For example, the student worksheet provided an opportunity to examine the student perceptions during the interaction within the simulation, and a survey provided an opportunity to examine particular areas of interest to the researcher immediately after the student experience. Furthermore, semi-structured interviews provided opportunities to give depth to the research findings that may not have been illuminated through previous collection methods.

Thick description

Transferability of the account is another way to enhance the credibility of the study (Creswell & Miller, 2000). Providing a thick description of the setting, the participants, and the themes of a qualitative study allows the reader to become situated in the experience (Creswell & Miller, 2000) thus enhancing the possibility of the results of the study to transfer to another setting (Merriam, 2009). As compared to a thin description which is a superficial factual account, a ‘thick’ description described by Ryle (1949) and later developed by Geertz (1973) is a rich detailed account of the field experience, or in this study, a detailed account of the simulation experience, in which the researcher provides rich descriptions of the participants’ experiences of the phenomena in addition to the contexts in which those experiences occur. The researcher attempts to create “verisimilitude” (Creswell & Miller 2000, p,129), meaning, a thick description of the phenomenon is sufficient enough in details, context, and contextual meaning to enable the reader to transfer the information to similar contexts and settings (Geertz, 1973)

Researcher Bias and Assumptions

Described as researcher reflexivity, the clarification of the researcher's beliefs, bias, and assumptions from the beginning has been described as a method to increase validity and integrity of the researcher (Creswell & Miller, 2000; Lincoln & Guba, 2000; Merriam, 2009). Informing the reader of the researcher's position and any bias that may have been introduced into the interpretation will help the reader better understand the researcher's interpretive process (Creswell & Miller, 2000; Lincoln & Guba, 2000; Merriam, 2009). The historical, social, and cultural forces that may both inform and bias my interpretations are as follows. I have been in the radiology profession for over 20 years with the majority of this time spent as a healthcare provider until transitioning to an educator of radiologic sciences in a higher education institution. My philosophical assumptions and biases may be influenced by a personal and professional desire to improve patient and student outcomes through technology and protocol related research while also maintaining high standards for patient care.

Through personal clinical experiences when caring for patients I found early on in my career that improvements in technical skills gained by my increasing knowledge did not always improve my practice. It was not until I began to look closely at my skills in patient-centered care that improvements were realized. I learned through many observations of patients and healthcare providers that interpretations are extremely influential in the quality of patient examinations and, likewise, the quality of patient care. I believe the ability of a healthcare provider to provide a complete and accurate exam may be affected by his or her own personal history that may include his or her culture, personal experiences with pain or disease, or even his or her own absence of pain or disease. For example, an MRI technologist who has never experienced claustrophobia may not fully understand a claustrophobic patient's fear, and, likewise, may lose patience with his or her patient. This can cause increased stress for both and the patient may not receive a proper diagnosis as a result of not completing the exam. Patients also arrive with their own preconceived notions of how they will be cared for as a result of personal interpretations of disease, pain, and experiences with prior care. I believe health care is largely affected by the ability to interpret the experiences of others, learn from these interpretations, and effectively incorporate these interactions into transferable knowledge. I bring this background of human behavior into my research as I believe the researcher, the participant(s), and the reader(s) will have differing perspectives, especially in scenarios that include technological skill, patient care, and ethical dilemmas. Similar to my patients, I feel a researcher who gains a close and personal understanding of the participants will be more effective in answering research questions that are subjective in nature.

Additionally, I hold an interpretive framework based on pragmatism. I have a desire to conduct research that solves a problem or is instrumental in developing solutions for problems. Creswell (2013) describes the characteristics of the pragmatist as having an affinity for practical outcomes for conducting research, not being committed to any one assumption, and conducting research using whatever research methods needed to solve the problem or answer the research question (Creswell, 2013). Although I have proposed an inductive design for this study, I can identify with Creswell (2013) when he stated that pragmatists do not focus on methods, and, "Reality is known through using many tools of research that reflect both deductive (objective) evidence and inductive (subjective) evidence." (p. 37). I feel the interpretive framework I bring to research that has been developed thus far has been based on the needs of my profession, my patients, and the needs of my students.

Assumptions

There are three assumptions that underlie this research study. A description of each with measures to assure the assumptions were met are described here.

1. To assure the participants answered the interview and survey questions in an honest and candid manner. To account for this, the survey was delivered completely online through Survey Monkey with full disclosure that stated the survey was voluntary and anonymous, but that the survey would aid in the development of future scenario-based simulation activities. The interviews were conducted only after a course grade was given. All interviews were made confidential by assigning a number to the participants and the participants were made aware that the information was anonymous and was going to be kept in a secure file in the researcher's computer.
2. The inclusion criteria of the sample were appropriate and therefore, assured that the participants all experienced the same or similar phenomenon of the study. The entire class performed the activity as part of the spring term course regardless of their participation in the research study.
3. To assure the participants had a sincere interest in participating in the research and did not have any other motives, such as getting a better grade in the course. The instructions for participation in the study were explicit in

describing that participation in the study did not affect their grade or standing in the radiology program in any manner.

Delimitations and Limitations

Delimitations that limit the scope and define the boundaries of this study include the exclusion of allied healthcare students outside of radiology and radiology students who are not in advanced imaging courses. These were eliminated from the study as the intervention was designed for advanced imaging curricula. Additionally, radiology students from institutions outside of Midwestern State University were eliminated so that an understanding of the intervention within the particular context could be explored. The data from outside of the MSU program may not be as robust as data from within, as the virtual scenarios were designed specifically to follow the MSU radiology curriculum within the online program.

Merriam (2009) suggests the researcher disclose to the readers a description of the limitations of the study that are beyond the control of the researcher that may affect the outcome of the study. This study's limitations consisted of small sample size selection, time constraints, and the instructor as the researcher for the introductory portion of the course.

The advanced imaging courses, Principles of CT and MRI Applications are usually only offered one semester per year limiting the number of participants available for the limited amount of time available for this study.

Another limitation involved the researcher as the instructor for the introductory portion one of the two courses, the MRI course. Since the courses are usually only taught by one professor at this university, it was not possible to fully separate the researcher from the participants. However, the course was taught by a different professor after the first six weeks of the course for this particular semester providing opportunities for interviews outside the researcher's courses. The second course, CT, was taught fully by another professor. Ethical considerations include undue influence, coercion, and incentives that may undermine the voluntariness of a participant's consent to participate in research. Strategies for overcoming ethical considerations for instructor as researcher are similar to the strategies previously mentioned for satisfying the assumptions of the data collection. In an effort to assure ethical concerns are neither realized nor perceived, the following measures were taken.

1) The invitation to participate was handled entirely online by another professor in an online invitation indicating that he/she was sending the email on behalf of the researchers and that anonymity will remain in effect until after the course grade is awarded. In the invitation, assurances were explained to the students that no penalties would result by not agreeing to participate in the research. Only after the course grades were given was the researcher made aware of who volunteered to participate and the consent forms were made available to the researcher.

2) The survey instrument was made available completely online and anonymous

3) Reviews of the worksheets for the study were conducted after the course grade had been awarded and after the researcher was made aware of who consented to participate

4) Interviews were conducted after the course grade had been given.

CHAPTER 4: RESULTS

Overview of the Study

A mixed methods case study following a concurrent design was the approach used to investigate the students' perceptions of the design and integration of a virtual scenario-based simulation. This online formative activity was developed for and integrated into two advanced modality courses for undergraduate radiology students. To gain a better understanding of the students' perceptions of their experience and to thoroughly explore the impact of this intervention within this context, integration of qualitative and quantitative methods was used to answer the specific research questions in this study.

1. For the group of advanced imaging radiology students in this case study, how does the design of the virtual scenario-based branching simulation impact the students' satisfaction with the learning experience?
2. For the group of advanced imaging radiology students in this case study, how does a virtual scenario-based branching simulation impact the students' confidences in their ability to make appropriate decisions in real-world practice?

To answer these questions this case study provided an exploration of the experiences of these particular students with the scenario-based simulation activity. To provide meaning to their experiences triangulation of multiple forms of data were used. The satisfaction with the learning experience was answered using the survey, the student worksheets, and the semi-structured interviews. Confidence in making appropriate decisions in real-world practice was answered by also using the survey, the student worksheets, and the semi-structured interviews, and by also analyzing how the results of the satisfaction question led to confidence in learning. Each piece provided different perspectives through time and through reflection. For example, the student worksheet provided an opportunity to examine the student perceptions during the interaction within the simulation, and the survey provided an opportunity to examine perceptions immediately after the student experience. Furthermore, the semi-structured interviews provided opportunities to give depth to the research findings that may not have been shown through the survey or the student worksheets.

This chapter outlines the participant characteristics of the study followed by an examination of the results. The organization of the quantitative and narrative data will be divided by each research question, the themes that emerged that attempt to answer each research question, the quantitative results from the survey, then quantitative results combined with supporting qualitative results, and then a convergence of the results. For clarity, in the context of this chapter the terms 'simulation' and 'virtual scenario-based simulation' are synonymous.

Participant Characteristics

Ultimately, all students in both courses participated in the study. Fifty-seven students completed the anonymous survey, 33 gave permission for the researcher to analyze his or her worksheet assignment, and 15 students volunteered to complete an interview. However, of the 15 interviewees, four did not schedule an interview time, so 11 actual interview sessions were completed. During the data collection process, it was found that saturation occurred for this group of participants at the sixth interview. Also, it should be noted that after the interviews, member checking was performed and the data was brought back to the participants through email. Two of the 11 participants participated, and both participants were satisfied with the narrative and the interpretations.

From the demographic data collected from the surveys, all of the participants were similar in that they were familiar with online learning and they were all enrolled in at least one advanced modality course. Of the students who participated in the study, 30 were enrolled in the online CT course, 24 were enrolled in the online MRI course, and three were enrolled in both courses. Additionally, all participants were concurrently working towards the online Bachelor of Science in Radiologic Sciences degree. Ages ranged from 18-54 years old, and the range of years of experience in the field of radiology was from 1-21+ years. Forty students were females and 17 were males. The majority of the students claimed they were either confident or extremely confident when using virtual technology (Table 5).

Table 5. Participant Characteristics

Age Range (yrs)	18-24	25-34	35-44	45-54	Skipped
Frequency	7 (12.3%)	29 (50.9%)	14 (24.6%)	6 (10.5%)	1
Radiology Experience	1-5 yrs.	6-10 yrs.	11-20 yrs.	21+ yrs.	Skipped
Frequency	31 (54.4%)	14 (24.6%)	10 (17.5%)	2 (3.5%)	0
Confidence with Virtual Technology	Not Confident	Somewhat Confident	Confident	Extremely Confident	Skipped
Frequency	0	5 (9%)	28 (49%)	24 (42%)	0
Advanced Modality Course	CT	MRI	Both		
Frequency	30 (52.6%)	24 (42.1%)	3 (5.2%)		
Gender	Female	Male			
Frequency	40 (70.1%)	17 (29.8%)			

The interview participants were each given a pseudonym for the purpose of anonymity. Table 6 provides the interviewees' current radiology experience, years in the profession, which advanced imaging course they took, their story-based simulation experience, and simulation experience. There were varying levels of experience in radiology and varying levels of experience in different modalities. It is noted that few of the participants had any prior experience with story-based simulations and few had any prior experience with simulations of any kind.

Table 6. Interview Participants' Characteristics

Participant (Pseudonyms)	Current Radiology Experience	Years in Profession	Advanced Modality Course	Story-based Simulation Experience	Simulation Experience
Alecia	Nuclear Medicine and CT	5+	MRI	None	None
Andy	Diagnostic	5+	CT	None	None
Ava	Ultrasound	10+	CT	None	None
Daniel	CT and Clinical Instructor	15+	CT	Some in classroom	None
Elizabeth	Sales	15+	CT	None	None
Emma	Interventional Radiography	5+	CT	None	None
Jennifer	CT	5+	CT and MRI	None	Once in class
Jeremy	Surgery	10+	CT and MRI	None	In class with role play
Jesse	Management	10+	CT and MRI	In class/ role play	None
Owena	CT	10+	MRI	None	None
Rachel	Diagnostic but training in MRI	4+	MRI	None	In-class/role play

Research Question 1-Satisfaction

Analysis of the data that were significant to the question, “For the group of advanced imaging radiology students in this case study, how does the design of the virtual scenario-based branching simulation impact the students’ satisfaction with the learning experience?” revealed six distinct themes; Objectives (Task deliverables) and Scenario Resources, Fidelity (Realism), Feedback and Support, Problem Solving, Perceived Usefulness, and Affect. The themes in this section were generated from the prior research on the simulation design components, the memoing, the survey categories, the student worksheets, and the interviews. The survey categories loosely guided the interview questions and the initial code sets for the qualitative data. However, the memoing that took place during the worksheet collection and during the transcribing of the interviews revealed additional design elements not found in the surveys that affected both satisfaction and confidence. After memoing took place the survey categories became sub-categories for the initial three code sets, 1) each design strategy; 2); each description of confidence; and 3) satisfaction elements not outlined in the design strategies, thus supporting the qualitative findings. As the first-cycle coding progressed and in vivo coding took place, additional nodes evolved and were added to these categories. The final themes emerged from second cycle coding in which more distinct themes were able to be derived.

As the focus of research question number one was to determine the impact the design characteristics had on satisfaction with the learning experience, an overall view of the participants’ satisfaction was first evaluated from the sub-section of the survey, Satisfaction with the Learning Experience. The results from this survey section indicated participants were indeed satisfied with the learning experience. It was found that all of the survey participants indicated the teaching methods were helpful and effective. All of the participants indicated they felt the simulation provided a variety of learning materials and activities to promote their learning, and, all of the participants indicated they enjoyed how the simulation was taught. Almost all of the participants felt the activity was motivating and helped them to learn (94.8%), and 96.5% felt the way the simulation was taught was suitable for the way they learned (Table 7).

Table 7. Student Satisfaction with Current Learning: Student Satisfaction and Self-Confidence Scale

Evaluation Item	Skipped	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Mdn (IQR)
The teaching methods used in this simulation were helpful and effective.	0	0	0	0	10 (17.5%)	47 (82.5%)	5.0 (0.0)
The simulation provided me with a variety of learning materials and activities to promote my learning.	0	0	0	0	11 (19.3%)	46 (80.7%)	5.0 (0.0)
I enjoyed how the simulation was taught.	0	0	0	0	16 (28.1%)	41 (71.9%)	5.0 (1.0)
The teaching materials used in this simulation were motivating and helped me to learn.	0	0	0	3 (5.3%)	14 (24.6%)	40 (70.2%)	5.0 (1.0)
The way the simulation was taught was suitable to the way I learn.	1	0	0	1 (1.8%)	17 (29.8%)	38 (66.7%)	5.0 (1.0)

a. Likert scale: 1 = Strongly Disagree 2 = Disagree, 3 = Undecided (neither agree nor disagree), 4 = Agree, 5 = Strongly Agree
b. Mdn=median, IQR= Interquartile Range

Specific design characteristics that contributed to the participants' satisfaction were then explored using the five Design Scale sub-sections of the survey and results from the qualitative data as described in the following themes.

Theme 1: Objectives and Scenario Resources

Theme 1 describes a key design characteristic participants identified as important to their satisfaction with the learning activity. The results of the qualitative and quantitative data indicated that it was important to the participants that the scenario provided a clear outline of the objectives along with an appropriate pool of scenario resources unique to each situation. The virtual scenarios were designed around specific learning objectives that aligned with the course modules (Appendix J), and scenario resources that were incorporated into the beginning and throughout that included instructions, suggestions for prior learning such as course modules and textbook information to be completed prior to attempting the simulation, and artifacts that may be needed within the scenario to solve the problems as they emerge, such as electronic health records, checklists, mnemonics, images, videos, and external professional documents. This theme described the learner's preparedness intellectually and physically to successfully resolve or complete the scenarios. Overall, the objective information and scenario resources that were integrated into the scenario-based simulation were considered to be an important design element that assisted the students in their own learning. Fifty-seven students provided survey responses, 16 students made 26 specific references to objectives and scenario data in their worksheet reflections, and the interviews provided an analysis of the objectives and scenario data that were important to the participants with nine of the interviewees contributing 59 references about the objectives and scenario data.

Survey Results

The sub-section of the Simulation Design Scale, Objectives & Information, provided quantitative insight into how this design characteristic impacted radiology student's satisfaction with the learning activity. In this section, participants were asked whether the objectives and scenario resources were important to them and whether or not they felt they were successfully included in the design of the simulation. It was shown that 66.6% of the students identified these items as "Very Important" to them and 28.7% of them found the items to be "Important" (Table 8).

To describe whether the students' expectations of the objectives and resources were realized within this activity the students indicated in the survey how strongly they felt about each of the following statements. It was determined that participants did feel there was enough information provided both in the beginning and throughout the simulation to provide direction and encouragement (91.3%). They felt the purpose and objectives were clear to them (91.2%). They indicated there was enough clear information to help problem-solve (91.3%), and that the cues were appropriate and geared to promote their understanding (93.0%) (Table 8).

Table 8. Objectives & Information: Simulation Design Scale

Evaluation Item	Skipped	1	2	3	4	5	Mdn (IQR)
There was enough information provided at the beginning of the simulation to provide direction and encouragement.	2	0	0	3 (5.3%)	16 (28.1%)	36 (63.2%)	5.0 (1)
Importance to you*	4	0	1 (1.8%)	1 (1.8%)	17 (29.8%)	34 (59.6%)	5.0 (1)
I clearly understood the purpose and objectives of the simulation.	3	0	1 (1.8%)	1 (1.8%)	15 (26.3%)	37 (64.9%)	5.0 (1)
Importance to you.*	0	1 (1.8%)	0	2 (3.5%)	16 (28.1%)	38 (66.7%)	5.0 (1)
The simulation provided enough information in a clear matter for me to problem-solve the situation.	2	0	1 (1.8%)	2 (3.5%)	16 (28.1%)	36 (63.2%)	5.0 (1)
Importance to you.*	0	0	1 (1.8%)	1 (1.8%)	17 (29.8%)	38 (66.7%)	5.0 (1)
There was enough information provided to me during the simulation.	1	0	2 (3.5%)	0	19 (33.3%)	35 (61.4%)	5.0 (1)
Importance to you.*	1	0	0	1 (1.8%)	16 (28.1%)	39 (68.4%)	5.0 (1)
The cues were appropriate and geared to promote my understanding.	2	0	0	2 (35%)	16 (28.1%)	37 (64.9%)	5.0 (1)
Importance to you.*	0	0	0	0	16 (28.1%)	41 (71.9%)	5.0 (1)

a. Likert scale: 1 = Strongly Disagree 2 = Disagree, 3 = Undecided (neither agree nor disagree), 4 = Agree, 5 = Strongly Agree
b. Importance scale: 1=Not important 2=Somewhat Important 3=Neutral 4=Important 5= Very Important
c. Mdn=median, IQR= Interquartile Range

Qualitative Results

Similar to the positive results in the survey for the question, “There was enough information provided to me during the simulation”, the remarks the students made on the worksheets and from the interviews described how the students felt the objectives and scenario resources were able to improve their satisfaction. When students provided their reflections on the worksheets it was noted that several of them not only felt there was enough information provided, but that there was a good balance of information to promote their learning. The following excerpt from the worksheets describes this balance.

> Student worksheet: “I enjoyed the experience. I felt there was a good balance of useful information for the time spent in the scenario. Too much technical information would have been overwhelming. The amount of information presented was just enough to be useful in the field. More than this would have caused me to space out or shut down. The scenario held my attention and the number of slides was good.”

Additionally, several students felt the number of objectives that were listed provided them with a variety of information to be learned that they may not have been able to learn as quickly in a clinical environment. This also describes the survey question, “There was enough information provided to me during the simulation”. However, this shows the differences in perceptions of what is considered to be the correct amount of information. The following student enjoyed how the scenario represented many different days and experiences.

> Student worksheet: “I enjoyed virtual observation. Many of the matters that can be encountered in so many days/cases are consolidated in a single scenario. For example, there is patient care, HIPPA [HIPAA], contrast media reaction and extravasation, mood swings, etc. I felt like I am in a real CT suite with real patient. Navigation bars are easy to go through. Pictures are relevant. Videos offer extra knowledge.”

Another view of the correct amount of information can be seen in the many varying degrees of responses students made when reflecting on which scenarios were most meaningful to them and why. Based on these results, there was enough available information for each student to garner benefit from the scenarios individually based on their current learning needs.

> Student worksheet: “I found the first scenario to be the best because it enhanced my understanding of the different types of brain hemorrhages and how to identify them.”
>
> Student worksheet: “I really enjoyed the 2nd scenario because it was filled with so much information that could be useful in the real world. I like how there were [real] images of what happens if things go wrong with injections.”
>
> Student worksheet: “PE’s [pulmonary emboli] are also very popular so we will definitely be able to use the information more than the dissection. It is also more technical then the head/brain scenario so there is more to learn.”

The interview participants also described their perceptions of how the objectives and scenario resources impacted them, but in more detail. The survey question that indicated that the students felt, “the cues were appropriate and geared to promote my[their] understanding.” can be illustrated in Alecia’s description of the simulation. Alecia described her experience with resource gathering and how she perceived the information would be beneficial to her learning. It is noteworthy to mention that she recognized the value for her own learning after attempting the scenario when she did not set aside enough time for it, and, instead of continuing, she came back when she had plenty of time to use the scenario for her own satisfaction and benefit.

> Interviewer: Can you tell me about your level of engagement with the virtual scenario-based experience?
> Alecia: Well I definitely wouldn't miss work cuz bills gotta [sic] get paid, but I knew from the first time I did this, you know it takes a little bit to have fun,

> so I took my time. So the second time around I did this, I had a Saturday set aside for it. I liked to take notes alongside. Are all, like, I'm not sure if other students did this, but I actually have, like files, where if something came up I would print screen and you know, take it to another file and take notes on it, and I liked the pictures that you had picked out that's a good idea. Yeah, there's a lot of good information, like you had, like from the very first virtual scenario you basically had a bunch of like tricks and hints to remember like T1 and T2 and yeah, so I saved that one for studying for the finals. I wanted anything out there myself to use, like expecting like T1s at first in the race so really you would have a short time so you used a lot of the mnemonics and stuff.

Daniel described his experience with his exploration of the main objectives and additional learning that was available. He was very animated and detailed in his responses indicating his increased satisfaction with the amount of information available for his own learning. His account also illustrates the depth of the survey questions, "The simulation provided enough information in a clear matter for me to problem-solve the situation", and, "There was enough information provided at the beginning of the simulation to provide direction and encouragement" that many of the other students expressed as well.

> 1. [Talking about the storyline and objectives in CT - brain imaging]
> Daniel: Well I really like on the storyline, with particularly, with neuroimaging, when you were going into, like I think her name was Elizabeth if I can remember correctly, Elizabeth and Ashley and neural imaging, that checklist, as far as competencies, and how you were able to incorporate that prior to to scanning and stuff like that. I thought that was it was good… I liked how you incorporated a lot of the different types of bleeds. You know subdural, subarachnoid, extradural you know intracerebral. You had education under each one of those bleeds. You provided a video on every single one of them that shows you exactly, you know, from like the egg like you know lens shape, you know from the spaces, and the yeah the subdural. You you [sic] provided a great education on it. I thought it was a really really good opportunity, learning opportunity for people who don't know. A lot of this stuff I already know as I'm a CT veteran, but it was it was really good information, you know it just highlighted areas that I could see people who are not familiar with this. This is very informative information

2. Daniel: Yeah the way it's set up. I, you know what, the way it's set up…not different figures, you know, like for example, when you have like your preparation, and you use your, even in the beginning, you know you show the four parts. You know you have your preparation, your navigation, your decisions, your grading. Everything, you have everything. You've broken it down into different, you know parts, different stuff like that. Not only that, you got pictures, you know that that's just awesome. You know your pictures you know each one of your things you broke them down into different things, you know your missions, your scope of practice.

3. Daniel: Yes, I think these types of simulations would be good, because they set different examples, you know from contrast, to identifying patients, to it's like every step that you would normally take. You incorporated AIDET. I mean in this you have you got like the basic, you've got the main pillars on here that you're looking for as a technologist. So yes I I [sic] think yeah this is gonna [sic] be very good, very good you know. You got everything in here. I mean you're talking about contrast, you're talking about checkoff lists, identifiers. AIDET. You did good you got all the main pillars. You know the two identifiers; you know this it's it's it's [sic] very good.

Convergence

In all three methods of data collection, the participants appreciated how the objectives and scenario resources were incorporated into the design of the virtual scenario-based simulation activity. The quantitative survey results were supported by the comments students made about this design characteristic in both the worksheets and in the interviews. Overall indications were that in their own ways each student valued the objectives and the scenario resources that were presented allowing them to customize the experience based on their own learning needs (Table 9).

Table 9. Convergence Objectives & Scenario Resources

Quantitative Results	% Importance	% Satisfied	Supporting Qualitative Theme	Worksheets Frequency (# of comments)	Interviews Frequency (# of comments)
Objectives & Information	95.3	95.6	Objectives and Scenario Resources	>20 (26)	>20 (59)

It is noted that there were 4 students of the 57 who disagreed with one question each in this section. Further investigation revealed for the question, "I clearly understood the purpose and objectives of the simulation" one student indicated that he or she disagreed, however, he or she responded positively to the other questions in this section and there were no indications of this in the worksheets nor the interviews. Another student disagreed the simulation provided enough information in a clear matter for him or her to problem-solve the situation, and that this was not important to him or her. This student was also satisfied with all the other questions in this section. There were no indications apparent in the worksheets nor interviews as to why this student felt this way. Another two students disagreed as to whether there was enough information provided during the simulation. Correspondingly, these two students also indicated low confidence in their learning even though they both indicated they agreed or strongly agreed with all of the other aspects of the simulation experience. This also did not appear in the worksheets nor the interviews, and, since the survey and worksheets were completely anonymous it is not known if one of the interviewees answered these questions, so it is unclear what the motivations for these answers were.

Theme 2: Feedback and Support

The participants acknowledged that the integration of and types of feedback and support in the simulation was important to them. The categories of feedback that were referenced were instructional feedback, intrinsic feedback, and supporting feedback. As described in Chapter 2, instructional feedback provided the learner an immediate response and to an incorrect action providing a rationale and or explanation through written text and images if needed. The intrinsic feedback in the activity provided the learner with a response from the simulation that allowed the learner to experience (virtually) the result or consequence of his or her action. Supporting feedback referred to help that the student sought within the simulation. From the quantitative and qualitative data, participants indicated that all three forms of feedback were important to them, that all three were present within the simulation, and that the way all three were implemented into the simulation increased their overall satisfaction with the activity.

Survey Results

To demonstrate the participants' feelings about the feedback, responses to two of the quantitative sub-sections of the survey were evaluated; Feedback/ Guided Reflection and Support. Similar to the previous themes, participants indicated that the items concerning feedback and support were also important to them; 51.0% of the participants indicated that these characteristics were "Very Important" to them and 28.6% of the students identified these characteristics were "Important". However, in slight contrast to the design characteristics of Objectives and Scenario Resources and Fidelity (Realism), the overall percentage of importance was not as extraordinary; 79.6% as compared to 93.6 % and 98.1% respectively. (Table 10).

The participants did, however, widely acknowledge they felt the mechanisms of feedback were present and agreeable. For example, they indicated support was easily available within the simulation (82.5%). They indicated they were able to find help in the simulation (82.5%). The participants felt supported by the available feedback within the simulation (87.7%). The participants indicated the tips, feedback, and consequences helped them feel supported in the learning process (94.8%), and they felt the feedback was constructive (89.4%) (Table 10).

Table 10. Support and Feedback: Simulation Design Scale

Evaluation Item	Skipped	1	2	3	4	5	Mdn (IQR)
Support was easily available within the simulation.	2	0	2 (3.5%)	6 (10.5%)	14 (24.6%)	33 (57.9%)	5 (1.0)
Importance to you.*	0	0	0	6 (10.5%)	17 (29.8%)	34 (59.6%)	5 (1.0)
I was easily able to find help in the simulation.	3	0	2 (3.5%)	5 (8.8%)	18 (31.6%)	29 (50.9%)	5 (1.0)
Importance to you.*	2	0	0	6 (10.5%)	18 (31.6%)	31 (54.4%)	5 (1.0)
I felt supported by the available feedback within the simulation.	2	0	1 (1.8%)	4 (7.0%)	16 (28.1%)	34 (59.6%)	5 (1.0)
Importance to you.*	1	0	1 (1.8%)	6 (10.5%)	15 (26.3%)	34 (59.6%)	5 (1.0)
The tips, feedback, and consequences helped me feel supported in the learning process.	1	0	0	2 (3.5%)	18 (31.6%)	36 (63.2%)	5 (1.0)
Importance to you.*	0	0	0	5 (8.8%)	16 (28.1%)	36 (63.2%)	5 (1.0)
Feedback was constructive.	2	0	1 (1.8%)	4 (7.0%)	19 (33.3%)	32 (56.1%)	5 (1.0)
Importance to you.*	1	0	0	8 (14.0%)	21 (36.8%)	27 (47.4%)	5 (1.0)
The simulation activity allowed me to analyze my own behavior and actions.	2	0	1 (1.8%)	2 (3.5%)	18 (31.6%)	36 (63.2%)	5 (1.5)
Importance to you.*	1	0	18 (31.6%)	14 (24.6%)	10 (17.5%)	11 (19.3%)	5 (1.0)

a. Likert scale: 1 = Strongly Disagree 2 = Disagree, 3 = Undecided (neither agree nor disagree), 4 = Agree, 5 = Strongly Agree
b. Importance scale: 1=Not important 2=Somewhat Important 3=Neutral 4=Important 5= Very Important
c. Mdn=median, IQR= Interquartile Range

Qualitative Results

From the worksheets, 5 participants made 5 references to feedback and support of the simulation activity. The qualitative data from the worksheets and interviews indicated how the methods of feedback improved the participants' satisfaction. This data provided insight into the perceived usefulness of each type of feedback, and it also alluded to how the feedback was instrumental in providing motivation through the way the feedback was integrated into the branching design. Although this was present in the worksheet data, this was most notable in the interview sessions.

The interviewees were more vocal about the methods of feedback. Nine interviewees made 36 references to feedback and support. Several of them described the different ways they used the feedback to promote their own learning and several described how the feedback affected them while they proceeded through the simulation. The survey question that indicated the students felt that "Feedback was constructive", can be seen in the following student's description of the feedback.

> Jeremy: I didn't just click through it. I watched it, read them, paid attention. I went into most of the second and third area pieces and where it said like, where you could click on something and read extra stuff. I clicked on most of them. Some of the things I didn't just, you know, hit the next button when it allows you to just take the test at the end. I actually watched through and read and listened. I was also waiting for, to see if there was going to be an interesting fall at the end, which there was!

The survey question, "The simulation activity allowed me to analyze my own behavior and actions" was demonstrated by many students in their descriptions about the feedback. One of the most notable discussions was with Alecia. Alecia was anxious about making the wrong choices in the simulation, however, she said she overcame that because of the non-punitive aspect of the feedback. Once she was able to overcome her anxiety she used the feedback to guide her own learning.

> Alecia: oh yeah! so I got, I was anxious trying to make the decisions and the questions just because I know that I do, I really understand this, ‘let me go with this answer’, but I think that's good because it, you know, the whole point is to force you to question to see if you understand, but you know, in this setting there's no punishment for it, ‘Hey you were wrong, but maybe it's because of this’, so it all stands to benefit from it, now based on the no punishment phase of it.
> Alecia: But in a sense, they're kind of was punishment because if you pick something wrong somebody in this scenario would get hurt or you know something would happen
> Interviewer: How did you feel about that?
> Alecia: Well, being the sadistic person that I am, it was just like a win-win! So I'm like, ‘okay if I'm wrong, something funny is probably gonna [sic] happen, but if I'm right - but I mean I'm sure I probably speak for a lot of students, even if I accidentally got a question right I would still go back and pick every single answer just to see what the description would be afterwards. I liked the explanation that it wasn't just wrong, it was wrong this is this, and that's why it's not this, ok.

In the worksheets and the interviews, many of the students described how the supporting feedback was used and appreciated. This supported the quantitative questions in which the students positively responded to the questions in which they indicated that they were “…easily able to find help in the simulation”, and in which they, “…felt supported by the available feedback within the simulation”, and in which they felt, “the tips, feedback, and consequences helped me[them] feel supported in the learning process:” Many students made positive remarks about how they were able to review any needed information before making decisions and also how they were able to review and reflect on why incorrect decisions were wrong. The following comment provides an example of how one student, Jesse, used the support and guidance within the simulation.

> Jesse: I think how um you know the talking about that that you know cranial anatomy and all that and how links were available for me over there to follow the

> anatomy and go further along and to really enhance my, kind of refresh my anatomy knowledge, and go back to the scenario again, and then go there and look at those images, and you can pause the videos in between when you're scrolling through those CT scans and those are all helpful.

In the survey it was noted that a couple of students had trouble with the feedback. Although there was no way to determine what those particular students had trouble with, it was found in the interviews that one of the students did not realize there was a drop down menu on the side that would allow him to easily navigate through the scenarios to return to previous concepts and scenes. Andy admitted overlooking the instructions for this feature and, when this feature was described, he said this would have made things easier.

> Interviewer: When you went through the scenarios did you back up to review the concepts?
> Andy: Yes, this one was you know. I was thinking – When I went to filling out the worksheet, you know when I was confused on one thing, then I tried to go back, then I think I have to from the go to the very beginning and I think I have to fast-forward. I think so I think this one I don't like. Yeah there should be I don't know if it was there or not, but there should be, you know, something like the mini topics here, so that I can click on and then I can start from there. For example, if I am confused with for example there is a subarachnoid hemorrhage and then I am confused while filling the worksheet, and I have to go through the very beginning and then become you know keep point scrolling scrolling and then I think there was a little bit annoying. Though maybe I don't know how to do it or I couldn't go back to the same beginning page to look on it. I have to say that I don't like it okay.
> Interviewer: Yes, there was a menu option where you could do that. There was an index on the left. Did you find this in the instructions?
> Andy: yeah maybe you know we can in the very beginning when we there's instruction page you can like highlight in the bold and you know you know there's a button if you miss something. You can hit a button and go there. You don't have to keep scrolling. and do what did you before from the very beginning.

Convergence

In all three methods of data collection, the participants appreciated the three different forms of feedback that were present in the simulation. The satisfaction with the feedback was present in the survey and was supported by the comments students made in both the worksheets and in the interviews (Table 11).

Table 11. Convergence Feedback and Support

Quantitative Results	% Importance	% Satisfied	Supporting Qualitative Theme	Worksheets Frequency (# of comments)	Interviews Frequency (# of comments)
Feedback/Guided Reflection/Support	79.6	91.8	Feedback and Support	>1 (5)	>20 (36)

In the interviews, it appeared that instructional feedback, intrinsic feedback, and supporting feedback were important to the students and they also indicated the feedback was beneficial in promoting their own self-learning. Overall indications were that students perceived the feedback as useful and motivational.

Theme 3: Problem-solving

Problem-solving also emerged as important to the participants' satisfaction with the learning activity. The combined quantitative and qualitative data revealed that PBL characteristics were important regarding this strategy, such as identifying and analyzing problems, searching for and using resources to solve problems, that an appropriate level of difficulty in the problems was presented, and that they were able to appraise the outcome of solutions.

Survey Results

From the survey sub-section, Problem Solving, participants indicated that problem-solving activities were important to them; 65.7% selected “Strongly Important” and 29.8% selected “Important” (Table 12).

All of the participants agreed that independent problem-solving was facilitated, and the majority, 96.5%, felt they were encouraged to explore all possibilities of the problems in the simulation. Additionally, 98.2% of the participants indicated they felt the simulation was designed for their specific level of knowledge and skills, and 91.2% indicated the simulation allowed them the opportunity to prioritize assessments and care (Table 12).

Table 12. Problem Solving: Simulation Design Scale

Evaluation Item	Skipped	1	2	3	4	5	Mdn (IQR)
Problem Solving							
Independent problem-solving was facilitated	0	0	0	0	16 (28.1%)	41 (71.9%)	5 (1.0)
Importance to you.*	0	0	0	1 (1.8%)	16 (28.1%)	40 (70.2%)	5 (1.0)
I was encouraged to explore all possibilities of the simulation	1	0	0	1 (1.8%)	20 (35.1%)	35 (61.4%)	5 (1.0)
Importance to you.*	1	0	1 (1.8%)	2 (3.5%)	20 (35.1%)	33 (57.9%)	5 (1.0)
The simulation was designed for my specific level of knowledge and skills.	1	0	0	0	15 (26.3%)	41 (71.9%)	5 (1.5)
Importance to you.*	1	0	0	0	15 (26.3%)	41 (71.9%)	5 (1.0)
The simulation allowed me the opportunity to prioritize assessments and care.	2	0	0	3 (5.3%)	15 (26.3%)	37 (64.9%)	5 (1.0)
Importance to you.*	1	0	1 (1.8%)	2 (3.5%)	17 (29.8%)	36 (63.2%)	5 (1.0)

a. Likert scale: 1 = Strongly Disagree 2 = Disagree, 3 = Undecided (neither agree nor disagree), 4 = Agree, 5 = Strongly Agree
b. Importance scale: 1=Not important 2=Somewhat Important 3=Neutral 4=Important 5= Very Important
c. Mdn=median, IQR= Interquartile Range

Qualitative Results

Among the worksheets and the interviews, 11 students made 14 references to problem-solving. The positive results from the survey about students' perceptions of whether "Independent problem-solving was facilitated" and whether "The simulation allowed me[them] the opportunity to prioritize assessments and care" was supported by many comments in the worksheets and the interviews. The following references to these questions were derived from several problem-solving activities in the scenarios. For example, in each patient case students were presented with a physician's order for a CT or an MRI. The student had to work through the patient's medical record information and the patient interview to determine if the exam ordered was appropriate and safe. Once they determined what the proper exam would be, they were then supposed to work through protocols to obtain the proper images. Once the patient was scanned, they were then given the opportunity to evaluate the images for any critical pathology. Below are a few of the discussions about these experiences from the worksheets.

> Student worksheet: "I enjoyed the CT protocol questions. I do not know much about protocols and those questions really helped."

> Student worksheet: "Of the observed Exams the exam that I liked the most was the MRCP Exam. I always enjoyed doing these types of scans when I did MRI because I enjoyed the interaction with the patient unlike the plain brain or spine when the patient is just still while being scanned. I found this particular study interesting because gating is being used as well. In the scenario is was important for the tech [referring to this student] to make sure that the correct exam was being ordered by the doctor based on the patient's history and previous diagnosis. It is extremely important for the correct test to be ordered, and if not sure, the tech should make sure to ask questions and to confirm before proceeding."

> Student worksheet: "I enjoyed going over the AVM [Arteriovenous Malformation] in patient Thomas. I found this one interesting because we have a lot of nurses in my hospital that have the same attitude towards MRI safety as Mr.

> Thomas. The AVM rupture was a good scenario to help me piece together the patient's history and not just dismiss the pain as a headache."

The survey questions about whether the students were, "…encouraged to explore all possibilities of the simulation", whether, "the simulation was designed for my [their] specific level of knowledge and skills, and whether, "the simulation allowed me[them] the opportunity to prioritize assessments and care" were also illustrated in the worksheet and interview dialogue. The following two discussions provide an overall representation of these survey items.

> Interviewer: How does the simulation affect your confidence in clinical or laboratory decision-making situations?
> Jesse: I think it really helps quite a bit because it really addresses all the problems like history taking skills and what should we looking at when you're collecting that information and how you interact with a patient and how you calm them down. It covers many topics and even on top of that, also our emphasis was, you know, focus on your protocol, understand your protocol, and preparation is the key before you really start performing your study because, you know, you're prepared for all the variations that might occur during this scan, and same thing with uh, you know, what we saw, how you know when the order is placed to the time of study is done and what can transpire and what kind of, uh you have the compilation of different studies and different physicians and priorities and how you prioritize them so they were all covered in there pretty much

> Owena: I did feel like that it had a lot of information that you could use like the different links that you can click on and it opened up another window. So I thought it was a really good virtual scenario where it could really assist in you know learning and getting like I said 'thinking outside the box' so, you know, giving you information, but also applying that information to the clinical setting that's, you know, what makes sense.

It was noted, though, that one student in the survey indicated that being encouraged to explore all possibilities of the simulation and being allowed the opportunity to prioritize assessments and care were not necessarily important to him or her even though he or she responded positively to whether these items were included.

Convergence

In all three methods of data collection, the participants indicated the importance of having problem-solving activities in the learning process. The qualitative data supported the quantitative data in that students felt they could identify and analyze problems in the activity, they indicated there were appropriate resources to help them to solve the problems, and they indicated the problems were at an appropriate level of difficulty for their current skill level (Table 13). Overall indications were that students appreciated the problem-solving opportunities.

Table 13. Convergence Problem-solving

Quantitative Results	% Importance	% Satisfied	Supporting Qualitative Theme	Worksheets Frequency (# of comments)	Interviews Frequency (# of comments)
Problem-solving	95.5	98.2	Problem-solving	>1 (5)	>5 (9)

Theme 4: Fidelity (Realism)

Another significant design characteristic participants identified as important to their satisfaction with the learning activity was the ability of the scenario to provide realistic situations that were relevant to the participant's practice. Although fidelity in simulation as described in Chapter 2 focused on the level of realism and complexity of the simulation, the participants' in this study described realism as the realistic nature of the simulations with regards to setting, the character personas, the exams, the artifacts, related examples of actual real-life events, and the storyline. Both the quantitative data and the qualitative data results indicated this was a key determining factor in the participants' satisfaction with the learning experience. Several referred to their satisfaction while describing the scenario as "relatable".

Survey Results

The sub-section of the survey, Fidelity (Realism) of the Simulation Design Scale, provided quantitative insight into how this design characteristic impacted radiology student's satisfaction with the learning activity. In this section, participants were asked whether realism was important to them and whether or not they felt the simulation included this characteristic. This sub-section of the survey revealed that fidelity was indeed important with 82.4% feeling it was "Very Important" and 13.1% of the participants identified the items in this sub-section to be "Important" to them (Table 14).

Similarly, most of the survey participants agreed that the scenario resembled a real-life situation (98.2%) and that real-life factors, situations, and variables were present (98.3%). No participant selected "Undecided", "Disagree", or "Strongly Disagree" for any statement in this sub-section (Table 14).

Table 14. Fidelity (Realism): Simulation Design Scale

Evaluation Item	Skipped	1	2	3	4	5	Mdn (IQR)
The scenario resembled a real-life situation.	1	0	0	0	8 (14.0%)	48 (84.2%)	5 (0)
Importance to you.*	2	0	0	1 (1.8%)	8 (14.0%)	46 (80.7%)	5 (0)
Real-life factors, situations, and variables were built into the simulation scenario.	1	0	0	0	7 (12.3%)	49 (86.0%)	5 (0)
Importance to you.*	2	0	0	0	7 (12.3%)	48 (84.2%)	5 (0)

a. Likert scale: 1 = Strongly Disagree 2 = Disagree, 3 = Undecided (neither agree nor disagree), 4 = Agree, 5 = Strongly Agree
b. Importance scale: 1=Not important 2=Somewhat Important 3=Neutral 4=Important 5= Very Important
c. Mdn=median, IQR= Interquartile Range

Qualitative Results

Similar to the results in the survey, the responses participants made to the reflection questions in the worksheets and the dialogue that resulted from the interviews also revealed a connection between this design strategy and the participant's satisfaction.

The qualitative data provided an analysis of the effects the realistic attributes had on the participants' level of satisfaction. From the worksheets, 14 students made 14 references to fidelity, realism, or relatability of the simulation activity, and among the interview dialogue, 11 participants made 37 references to realism within the scenario. Similar to the quantitative survey results, the increased importance of this design characteristic was highly visible in the dialogue.

The interviews demonstrated both direct and indirect effects that the realism had on the participants. While some participants commented on the satisfaction they gained from the realism of the atmosphere and storyline, others were able to become more immersed as they were able to relate the experience to their own real-life experiences. These discussions expanded on the survey question in which students indicated that “the scenario resembled a real-life situation”. Among the reflections from the worksheets, one of the participants was able to relate to his or her own situation as a new student and the moral courage one must have in protecting patients from harm.

> Student worksheet: “Yes, I did. I liked the relatable experiences of having to work with grumpy temp techs. I also related to the tech aspiring to be a CT tech, and stepping in to be an advocate for her patients’ when “Eric” was failing to provide any quality patient care. This shows in a virtual scenario how important it is to follow protocol in every way.”

Similarly, Alecia was able to become connected through her own personal experiences and it is notable that she also alluded to moral courage.

> Interviewer: Can you expand on how you felt about the EMT coming in and thinking that he knew everything?
>
> Alecia: All just way too relatable [Laughing]! It happens every day so yeah sorry I just keep saying the same thing, good job at making it relatable, and I think that it's, you know, even better that you do that because I think it just prepares you for situations in the future knowing that everyone knows these things happen because they do. Prepares you for real life. Yes, everyone's got something to prove!

Similar discussions emerged from the interviews which further described the survey question, “Real-life factors, situations, and variables were built into the simulation scenario”. Several of these surrounded the trigger events in the simulation. As described in Chapters 2 and 3 the trigger events were real-life events that were intended to show an example of what has actually happened in real life that is also related to what the student is learning in that particular scenario day. Daniel was very moved by the fact that a young boy was actually over radiated while obtaining a CT exam. He intertwined his own clinical expertise into the situation and was then able to relate the experience to his own learning.

> Daniel: So I was like I really thought that article was like, you know, just hits home you know. You like put things in perspective and I'm trying to figure out who in their right mind would scan somebody a hundred and fifty-one times! Yeah having the head CT that lasts over an hour and a half. You know what, I do perfusions all the time. CTPs all the time and they don't take that long! I mean you're looking at two or three minutes or less than that you know. It is just continuous scans over the you know area of interest but you know I I do get concerned with the dose.
>
> And that was another fact that you incorporated about radiation safety and radiation doses and stuff like that and that was very informative it gives people a perspective on you know they you know people don't really understand you know how much radiation they're receiving the cat scan. It's just they don't know you know the long term latent effects stochastic but they don't they don't understand what's gonna happen. 'Though I'm fine right now' well in about ten years ask the people from Japan you know if they're still fine or what type of cancer have they developed. So you did a good job with that as well I've really enjoyed that their radiation safety aspect of that scenario.
>
> And they're real but yeah you know I enjoyed the articles. I like the fact that you have legit articles incorporated in these scenarios it's a it's very good very informative real-life situations. Because you could have these scenarios that you put together right, and they they make sense everything looks good, and they read well. 'Well let me show you how this happened in a 'real life scenario' and so that you hit that, you threw that article out there, and you're like, "Wow!", "Man!", "Oh my goodness!" "This is this is happening like right now!". It's just like the the fact that you did that. You just they complimented the virtual scenario. That's just my opinion. I want to know what's, what's real, what's out there. Sure I can learn this in the book but I want to know what's happening so that's good. That example was, was excellent! I like that!

<u>Convergence</u>

In all three methods of data collection, the participants valued the realistic nature of the simulation to reproduce an environment that emulated a clinical environment in regards to the realistic content, the character personas, the exams, the artifacts, related examples of actual real-life events, and the storyline. The positive quantitative survey results were reinforced by the multiple comments students made about this design characteristic in both the worksheets and in the interviews (Table 15). Overall indications were that students were satisfied with the storyline and the real-life decisions they encountered, which allowed them to relate the experience to a real environment and/or personal experience.

Table 15. Convergence Fidelity (Realism)

Quantitative Results	% Importance	% Satisfied	Supporting Qualitative Theme	Worksheets Frequency (# of comments)	Interviews Frequency (# of comments)
Fidelity (Realism)	98.1	100.0	Fidelity (Realism)	>10 (14)	>20 (37)

Theme 5: Perceived Usefulness

This theme describes how participants perceived the usability and value of a virtual branching scenario-based design as a way to individually improve learning satisfaction. The uniqueness of a non-punitive, repetitive, branching type scenario allowed each experience by each student to be tailored to the students' perceived needs at that particular moment. The students described the control over what they would learn, how they would approach their learning, and what they would take away from the experience. As such, participants provided individualized examples of what was useful to them. Forty-four students made 81 references to perceived usefulness in the qualitative worksheets and during the semi-structured interviews. Although there were many different benefits reported, references to the most widely mentioned categories of perceived usefulness were; application to future and current practice, enhancement of online learning, retention of learned information, and a desire to use similar activities as a learning method for other courses in their program of study.

Application to Future and Current Practice

While discussing their satisfaction, a number of students expressed their intentions of using their new knowledge in their current and in their future practice. This characteristic also closely overlaps with the self-efficacy and transfer theme that helps to answer the second research question of the impact of the activity on student's confidence in clinical decision making. The following comments illustrate how students perceived the activity as relevant.

> Student worksheet: "Of the observed exams my favorite the MRA of the brain, I found this exam most interesting because it relates most to my current field in the cath [catheterization] lab. I have actually participated in fixing AVM and brain aneurysms. I also found the imaging to be the most interesting, being able to see the arteries is such great detail without actually accessing an artery seems foreign to me but ultimately better for the patient. It is better for the patient because there are so many risk that come with actually performing a cerebral angiogram."
>
> Interviewer: So do you think doing the scenarios will help you in your clinical practice?
>
> Andy: so yeah definitely, definitely. Because the same scenario because the people who will be similar. So the name will be different but you know the face will be different but the CTs would be like inside of the people will be the same. So this is definitely a you know gives a better understanding of what the problem will be and what the people will be so these are the good projects
>
> Student worksheet: "I did not remember the first aid steps for burns being taught to me. I also was refreshed on the thermogenic risk factors to look out for. Going through the patient's exam really helped me grasp the importance of taking the time and reviewing each patient chart before placing them in the magnet."
>
> Interviewer: I know you're already working in MRI, so how do you think the simulation affects your confidence in clinical decision-making situations?

Rachel: It was helpful to see that [I was] kinda [sic] was choosing the right answers majority of the time.

Interviewer: Did it reinforce what you already knew?

Rachel: Yeah, I've never really been like tested on my clinical skills within my job so it was kind of cool to see that I knew what I was doing I guess.

Enhancement of Online Learning

Several participants focused on the usability and implications of this type of activity in an online course. This was an important characteristic to the participants, as all of these students were online students and had experienced different methods of instructional delivery in this environment. Comparisons with other online activities revealed a slight dissatisfaction with some of the students' other online learning experiences, and, as such, the participants revealed the need for more applications type activities in the online environment.

> Student worksheet: "I enjoyed this because it gave me the feeling of clinical experience working as a MRI technologist, which is something that is hard to get during an online class. I think this gave good real life examples of patients and issues that may arise."

> Ava: I thought it was more helpful because it was more hands-on, you know, clicking to the next page and clicking on different things like the chart and what not, it just, it, I'm a more hands-on person and I know a lot of people are as well, and I felt that being in an internet course kind of hinders you from the class room setting to do so, or you don't get all that feeling, you know, since it is on the internet, and I felt the scenarios definitely helped 'get that feeling back' and it's just a better learning for people that are more hands-on but can't be in a classroom

> Emma: Well I've taken, like I said, a lot of online classes and from being like here's your book and now you take a test on toward you know like lectures online that you actually watch and this and that and so I'm kind of seeing the whole gamut of the whole you know range that it can be, but the first time I've had a scenario and I really liked it you know just something that you know you could interact with more.

Even though Alecia liked the activity she described how she missed the social interactions and she made a suggestion to include a social component.

> Alecia: So I do like the virtual scenario versus a discussion board, because I think in a discussion board we're all just saying, “yes I like what you said about bread. I also like bread. Bread is great!” So it is much better than that. The only thing that if I had to say something on the negative side of the virtual scenarios if there was a way I do like, you know, in discussion boards I can see what other people are saying about stuff in the you know occasional meaningful response. So the only thing I guess I'm missing in the virtual scenario side of it is I wish there was a way that we could all almost have like a discussion based on something that's happening in the virtual scenario. Maybe like in a cloud setting so you ask something, “What did we all think about Phoebe doing this?” and then there's like a discussion board within the virtual scenario like you know discussing what happens and I can see what everyone else says about it too. What would be fun yeah discuss how you would handle it or how you did handle a place to ask a question like how we'd all handle something differently and then we all kind of you as always people who reflect on a similar situation that happened to them and how they grew from it

Retention of Learned Information

The retention of information from engaging in an applications type of activity was an important characteristic to several of the participants as demonstrated in the following comments. It is significant to mention that many of the participants referred to the mnemonics that were provided in the scenario resources. Memory aids are an important tool in high-reliability professions to avoid errors from becoming complacent in practice.

> Student worksheet: “SAMPLE, Tuck SOM chins will help me remember the proper assessment and ways to educate the patient. if this material is on the final and/or registry Tuck will help me remember what the proper positioning should be for reducing exposure to the eyes/patient.”

> Student worksheet: “SAMPLE will be a good memory aid in general for my work. It will allow me to ask relevant questions of patients. I am not sure if this would be on a registry, but it definitely is good for everyday use. Also, I think the scanning protocols for the brain would be a final or registry related item.”

> Student worksheet: “The burn prevention and after care was helpful in refreshing my memory in case of an incident.”

> Interviewer: What do you feel would make you feel more confident when learning, virtual scenario-based simulations, campus laboratory experience, or with actual patients?
> Jesse: Oh okay so, of course, virtual environment is still virtual right? you understand you really try to build your knowledge base and everything else but when the real will happen then you can bring that knowledge forward. I think what really helped me in that scenario was it kind of 'sticks to your memory better than just reading something', so it just, like, that's what I found interesting in that whole virtual scenario, was that I was able to like stick into my long-term memory better than just as you know short-term memory when something will be sometimes, memorize things so in that sense it's good but at the same time of course when the real world happened things can change but at the same time we have a foundation at least.

Course Recommendations

Many of the participants made suggestions for other courses they felt would benefit from this type of activity. In all, 11 students made course recommendations for 10 other courses. The following comments illustrate a couple of these conversations.

> Interviewer: How do you see these scenarios fitting in with online courses?
> Andy: No, no this of course, I would say this is helpful for classroom as well. Yeah hundred-percent! You know online is online we aren't there, but classroom even you know the scenarios in the real classroom they can also use this one to sharpen their knowledge about the patient care, technologies, that the scenarios it is helpful for both. I think not only you know there is no way we can compare this with this is bad, that is bad, no this is for both.

> Interviewer: How do you see virtual scenario-based simulations and online courses fitting together or not fitting together?
> Jesse: I think that they have strong future I can see that especially the modalities we deal with even x-rays CT MRI any of the modalities. Not now the other subjects for example philosophy and those kind of things, they're different subjects, but in these things where they're practical things the way they are these are real time scenarios that things are happening in the real world this should be introduced in each course and they'll be extremely helpful not only just from the overall workflow understanding perspective but also to reinforce the knowledge.

Convergence

Participants acknowledged the overall benefits of the simulation activity in their descriptions of perceived usefulness. Although unique to each student, students indicated perceived usefulness in four primary categories. The worksheet data and the interview data were similar and described the categories of application to future and current practice, enhancement of online learning, retention of learned information, and a desire to use similar activities as a learning method for other courses in their program of study (Table 16).

Table 16. Convergence Perceived Usefulness

Qualitative Theme	Qualitative Sub-themes	Worksheets Frequency (# of comments)	Interviews Frequency (# of comments)
Perceived Usefulness	Application to Future and Current Practice, Enhancement of Online Learning, Retention, Course Recommendations	>20 (30)	>20 (51)

Theme 6: Affect

This theme also emerged from the qualitative worksheets and interviews. The participants' increased level of engagement and immersion with the scenario-based simulation became apparent while collecting and analyzing the open-ended qualitative data. Although the use of an antagonist and instances of comic relief were interjected into the design to maintain the flow of the storyline, the positive effect it had on student satisfaction indicated a need for further examination. The role of the participants, their interactions with the antagonist, and their interactions with the storyline in which the branching design gave them some control over the outcomes of the story invoked several emotions and reactions among the participants. Many participants indicated this increased their interest thus contributing to their satisfaction with the learning activity. The most common emotions revealed by the participants were excitement, feelings of poetic justice, inner conflict about the antagonist, and humor. There were 91 references to this theme among 46 participants, making it the most referenced theme among the qualitative data for design characteristics.

Excitement

Many students became animated when they spoke about the parts of the activity that were meaningful to them. Discussions with Andy and Ava demonstrate a few of these conversations.

> Andy: So you know on other ones [comparing other online activities]
> we can't imagine that we were there. Like this is almost like watching a movie. Like we are deeply in the, you know, inside of the character, by as I mean I would think that that the new tech is, is me myself!
> Otherwise, I might just be paying attention to skipping just to the questions to make sure I get it right. It's like a required fun! … Forced fun, I agree with all of it!
>
> Ava: I was actually really interested which caught me by surprise because I'm very I can't sit still for too long. I have to get up and do stuff and I didn't even realize how quick I went through it [time distortion]. I guess I liked it that much because I did them all at the same time. Back to back. Yeah, I was very interested in it!
>
> [MRI] Alecia: Are these characters at all based on real people and from your student experience? I was hoping there'd be like a story of it, you know one tech who was just mean to you or something. [This participant became so involved in the story she wanted to know if the storyline was based on a true story]
>
> [CT] Elizabeth: I felt it really represented real actual stories. I mean it was, it was very 'relatable' to real life!
> Yes! absolutely I love how the story continued in all of them - it wasn't quite as exhilarating as Game of Thrones but [laughing] Yeah, if you had a bigger budget for a graphics - I'm sure, oh no kidding, really, you've probably come up with a million-dollar or billion-dollar idea. Anything associated with health care, I mean

> I've sold health care products since 2005, I know you know these monitors that from mammography, you know you slap an FDA approval on it, it goes up to $13,000

Role

Many of the students became quite involved with the storyline and the role they each played. Jesse described his sense of immersion.

> Jesse: Yeah uh-uh, it was really good! I liked it, and even like you know how that setup was. How the information was presented about the patient itself and what backgrounds they had and how it started there… it was kind of very interesting to me, like I was your 'part of their whole storyline', so it was such a like a real-time experience. I felt like I was doing it and I was dealing with a patient and I was you know, like really taking the history and how then what the next steps are and everything was just phenomenally set up and you know.
>
> Interviewer: What benefits have you gained from your virtual simulation experience?
>
> Jesse: Yeah, and no, I think I was extremely happy, and I was really involved in them! I know when I was going through it and I would kind of almost like got 'sucked into it' and where I've really enjoyed it and I never, you know I, to be honest with you I've went over twice just to enjoy what was going on and your you know your student it's like a story building going on so you must have some kind of background in story writing or something, do you have that in your background?
>
> Interviewer: No, just a radiology background
> Participant: No? well you should think into that yeah yeah [sic]

Feelings of Poetic Justice

Several students became immersed with the characters and the storyline. They became emotionally charged when describing their experiences and displayed feelings of poetic justice for the antagonist in the story. A few of the students also described the learning that occurred through this emotion.

> Student worksheet: "The 3rd scenario was my favorite because not only did I learn how to do a CTPA scan (which I have never done), and identified a PE

[pulmonary embolism], but because there was more action at the end. I haven't liked Eric since the beginning and he was the one stealing evidence off the computer and finally got what he had coming to him." [The storyline seemed to have kept the student's interest as he or she reflected on both the poetic justice and the objectives of the last scenario]

Student worksheet: "The MRA brain of Evan Thomas (day 4) was my favorite because the links provided interested information. I've always heard of AVM's on medical shows but didn't know what they were. I also can't deny that I enjoyed phoebe getting 'stabbed' with scissors. That was funny!"

Student worksheet: "Scenario – Thomas – after Phoebe was struck in the head with scissors… I bet from now on…. Phoebe will be more aware and implement her MRI safety training and not conduct her profession with such a "loose cannon" attitude."

Daniel: How it ended with Eric, yeah being fired! Yeah, I think that that was pretty it's really good! [the participant became louder and his rate of speech increased as he continued this conversation] I really really thought that you know that was that was a good a good ending. It was solid because he deserved it! He definitely deserved it, but I couldn't believe that you know it went down like that at the very end! It was just like hard to believe, but you know what I mean, that you know people would do this type of stuff, but it does happen!

Inner Conflict About the Antagonist

Some students portrayed some inner conflict with the antagonist. This was sometimes portrayed as a struggle between poetic justice and caring about the injuries that the antagonist endured. For some students, they became frustrated with the virtual characters.

Student worksheet: "Eric is arrogant and ignorant at the same time and needs re-education STAT, his ambivalence led to extravasation in the pt's [patient's] hand and a pt [patient] fall" [this was in the worksheet data so it is unclear if the meaning behind this was sarcasm or anger]

Daniel: [while talking about violating HIPAA and medical identity theft in the scenario, the student's pitch and rate of speech changed dramatically as he continued this conversation]

It's crazy! and it's crazy that people actually you know, are that gutsy to to [sic] do it! You know what I mean? I mean it's just you know you don't deserve to be in this field if that's what you're doing with people's information. People will trust you and they put you in charge and we're privileged to be in the situations that we are in, and you know to be able to render care to these patients during their time of need. You know these people are going through the most difficult time of their lives! You know either they're being diagnosed with cancer or they're dealing with something that could be life-threatening or you know they just lost somebody.

Interviewer: Can you expand a little bit on some of the details that were meaningful or maybe troublesome to you about the story itself?
Emma: kinda [sic] like when he [the technologist Eric] disappeared it almost made me a little bit angry. You know you got this right cuz [sic] you just wanna [sic] you know grab him and shake him 'herself' [referring to the student's character in the scenario, she was mixing reality with the virtual world here]. Also, I guess I was, you know, I always had an 'annoyed' feeling at the manager herself because like she threw that poor girl into doing CT! and just was kind of like, 'Oh you should know how, here you go!'

Learning

One of the students, Owena, described the storyline from a learning perspective. She was able to connect the experiences she encountered in the story directly to her own learning needs.

[MRI] Owena Interviewer: Can you expand on how you felt about the storyline? How it evolved from when the new tech arrived to the end where Phoebe was injured and the EMT also had a medical emergency, can you expand on your feelings about the evolution of the story?

Owena: Yes, yeah I definitely I thought that it was it kept the the [sic] story interesting but it also wasn't like it wasn't a far-fetched far-fetched situation. It was something that could possibly happen. I mean it was something showing like hey this is one of this is the thing that could possibly happen and it's not like you know not something that would be way far-fetched out of out of nowhere something that you know since especially since she was just kind of like 'oh come on in' and you know he thought she knew him and he knew everything and so yeah it was interesting.

[Owena went on to speak of the virtual patients' histories and evolution of the patients through the scenario]

Inteviewer: How did you feel about the interactions of the characters?

Owena: I did feel like, um, I felt like you know I wanted to know what was gonna [sic] happen next to the patients. You know I wanted to know, you know, how this would affect this, so yeah, it was, I liked it a lot

Interviewer: So if the story would have ended halfway through would that have disappointed you?

Owena: Yeah I think so, I think I'm, I'm glad with the evolution of the story because it didn't start out with, like, you know everything's falling apart. It was more just like, okay we'll look at this and this, and that's okay, so then we'll go the next step, and then this is something else that could really really go wrong. [this also represents scaffolding]

<u>Feelings of Fun and Humor</u>

Participants indicated that they had fun with the simulation and many referenced experiences that were particularly enjoyable or humorous to them. Many indicated this kept them engaged and motivated to continue.

Student worksheet: "The 3rd scenario, it may not be the whole point of these scenarios but I loved that Eric was the bad guy."

Student worksheet: "I did. I enjoyed the ever so often jokes that kept me awake and made the cases more realistic, interesting and hilarious. I also think this depicts the student perspective well."

Alecia: [Laughing] Yeah-crazy stuff! Things, because you, you know, you with the storyline and the narrative you make us not like Phoebe, so I'm like 'yeah! Scissors to the head!' Very Game of Thrones!
Alecia: So I found it very relatable and especially in your MRI class I didn't know how it was gonna [sic] be there. I was like, you know laughing. So I was like, wow! This is literally how it is! I might as well get a clinical credit for this!
Interviewer: I'm glad it was relatable.
Alecia: Mission accomplished!

Ava: I thought it was all pretty relevant… but I even liked where someone got hurt! [this may be indicative of gallows humor] I believe I even liked that, that, that it felt like it like you're kind of watching and playing a little 'movie' or

something. I thought I thought I liked it a lot even though it might have not been relevant, but it kept you wanting to keep going and keep learning it and I liked it. It was interesting in the end, one of the the [sic] main characters, the travel tech Eric, he ended up getting arrested and yeah and he got shot or beat up or something
Interviewer: Yes, he got beat up.
Participant: That one, yeah, I like that part. It was funny and good, and interesting, and like I said, people kind of relate to that. They want to keep watching and keep as you're watching, you know, you're learning at the same time, so I thought that was, I think it's, a, important because college kids kind of get distracted and you need that kind of ability to keep from being bored.

Convergence

Participants demonstrated the effects the simulation had on them emotionally and how their response affected their motivation and learning. The worksheet data and the interview data were similar and described the participants' feelings of excitement, poetic justice, inner conflict about the antagonist, and humor (Table 17). Overall, the participants' emotional responses were perceived as beneficial to the participants.

Table 17. Convergence Affect

Qualitative Theme	Qualitative Sub-themes	Worksheets Frequency (# of comments)	Interviews Frequency (# of comments)
Engagement & Immersion	Excitement, Role, Retention, Feelings of Poetic Justice, Inner Conflict About the Antagonist, Storyline Learning, Fun & Humor	>10 (25)	>20 (66)

Research Question 2-Confidence

Analysis of the data that were significant to the question, "How does the design of the virtual scenario-based branching simulation impact radiology students' confidence in their ability to make appropriate decisions in real-world practice?" revealed two distinct themes; Confidence in Learning, and Self-efficacy and Transfer.

Confidence in learning describes the confidence students felt about the skills they practiced and their knowledge about caring for the types of patients presented in the simulation. This described confidence that the activity was relevant to what they were currently learning. Self-efficacy and transfer describe the participants' perceptions of their confidence in their ability to use their knowledge in clinical practice after performing the virtual simulation.

Theme 1: Confidence in Learning

Confidence in Learning emerged from the survey data and from the dialogue in the qualitative worksheets and the semi-structured interviews. This theme described how the participants were able to use the activity to apply their current learning.

Survey Results

From the survey, participants indicated they were confident in learning with the simulation activity; most participants felt they were mastering the content of the simulation activity (89.4%), most felt that the simulation covered the critical content necessary for the mastery of the MRI or CT curriculum (94.2%), all of the participants indicated that helpful resources were included (100.0%), all of the participants acknowledged that it was their responsibility as the student to learn what they needed to know from the simulation (100.0%), and most knew how to get help when they did not understand the concepts covered in the simulation (96.5%)(Table 18).

The following two questions from the survey specifically described the interrelatedness of confidence in learning and confidence in clinical decision making. The first question that demonstrated this connection was, "I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform the necessary tasks in a clinical setting". Of the 57 participants, 89.4 % indicated that they "Agreed" or "Strongly Agreed" with this statement. The second question was, "I know how to use simulation activities to learn critical aspects of these skills". This question produced similar results with 98.3% indicating they "Agreed" or "Strongly Agreed" with this statement (Table 18).

Table 18. Self-Confidence in Learning from the Student Satisfaction and Self-Confidence in Learning Scale

Evaluation Item	Skipped	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Mdn (IQR)
I am confident that I am mastering the content of the simulation activity that was presented to me in the simulation.	1	0	1 (1.8%)	4 (7.0%)	19 (33.3%)	32 (56.1%)	5 (1.0)
I am confident that this simulation covered the critical content necessary for the mastery of the MRI or CT curriculum.	1	0	0	8 (14.0%)	21 (36.8%)	27 (47.4%)	4 (1.0)
I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform the necessary tasks in a clinical setting.	0	0	1 (1.8%)	2 (3.5%)	18 (31.6%)	36 (63.2%)	5 (1.0)
Helpful resources where included to teach the simulation.	0	0	0	0	19 (33.3%)	38 (66.7%)	5 (1.0)
It is my responsibility as the student to learn what I need to know from this simulation activity.	0	0	0	0	16 (28.1%)	41 (71.9%)	5 (1.0)
I know how to get help when I do not understand the concepts covered in the simulation.	0	0	2 (3.5%)	0	19 (33.3%)	36 (63.2%)	5 (1.0)
I know how to use simulation activities to learn critical aspects of these skills.	0	0	0	1 (1.8%)	18 (31.6%)	38 (66.7%)	5 (1.0)
It is the instructor's responsibility to tell me what I need to learn about the simulation activity content during class time.	4	0	18 (31.6%)	14 (24.6%)	10 (17.5%)	11 (19.3%)	4 (2.0)

a. Likert scale: 1 = Strongly Disagree 2 = Disagree, 3 = Undecided (neither agree nor disagree), 4 = Agree, 5 = Strongly Agree
b. Mdn=median, IQR= Interquartile Range

Qualitative Results

Thirty-two participants made 88 references to confidence in learning. Among those, 12 participants interrelated their confidence in learning with their confidence in decision making. which supported the interrelatedness of confidence in learning and confidence in decision-making ability that was overwhelmingly present in two of the survey questions. Overall, however, the qualitative data supported the quantitative results and provided some insight into how the students gained confidence from using the simulation activity. Again, students responded well to the question of whether helpful resources were included to teach the simulation. The qualitative results from the earlier theme, Objectives and Scenario Resources overlap between confidence in learning and satisfaction. It appeared that the resources were an overwhelmingly important aspect of the virtual scenario-based simulation for both qualities.

The survey question in which students responded positively to, “I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform the necessary tasks in a clinical setting”, was also evident in many of the qualitative responses. To illustrate an increase in their confidence, several students commented on their confidence in learning as a comparison to a clinical rotation.

> Alecia: I think that it is much better than me reading a chapter and then taking a quiz because sometimes I'm like I'm not sure if I understand this other than, you know, verbatim understanding, just memorizing a definition, so I like it a lot better and compared to that and I think that it does make me more confident to see something in context. I mean you're literally giving me the confidence I would receive from a clinical rotation but in a virtual scenario, granted you know it's not in person, so it's not exactly the same thing, but you're putting those scenarios ‘literally’ right in front of us so I feel like I'm getting a very similar level of confidence from that then versus just reading something and taking a quiz

Interviewer: What benefits have you gained from your experience?
Alecia: It made MRI less intimidating, because with, without that experience I would probably think that I wasn't prepared enough to even conjure up the courage to ask an MRI tech like, ‘hey can I come and learn from you’, because now I feel, based upon those virtual scenarios, I still have a leg a little bit of a leg to stand on before I ask them, like I don't feel like I would be useless.

Other students described their confidence with the way the simulation was taught. They not only responded positively to the survey question of knowing how to use simulation activities to learn critical aspects of the skills, but they expanded on the types of skills that were most meaningful to them in their learning and how they could use the information going forward.

[Talking about meaningful experiences and non-punitive questions]

Rachel: So I like that you'd set it up that way so I'm not intimidated of picking the wrong answer, because then I'm not just, you know, I'm engaged in the story.

Student worksheet: “I learned a lot with the virtual scenarios. I’m not going to lie, I didn’t want to do them at first, but they actually did help me a lot! It’s nice that they actually put real life scenarios into perspective and help you figure out what you need to do while refreshing your memory on protocols, anatomy and even situations that you could be put in in real life and what to do in that case.”

Interviewer: How does the simulation affect your confidence in clinical or laboratory decision making situations?
Ava: I feel it's a precursor for any kind of scenario because anything can happen and it did give you insight of you know what can go on on a daily basis and I feel like it could prepare students to you know you know be prepared for things like that and that anything is possible.

The positive results of the survey question, “It is my responsibility as the student to learn what I need to know from this simulation activity” was reinforced when Jesse described how he was able to use the simulation to gain confidence in how he approached the learning.

> Jesse: Uhm so other online activities that I have done in the past they're pretty much either online forums or discussion forums where you can you know share your thoughts and people comment on it and uh what I have seen a lot of times it's like more like a formality for students right, and you know you're supposed to comment on two discussions and you go there, quickly skim through them, you know the content and they always are like, 'I like it, we do the same thing in the hospital', so it's really not meaningful, but what I have experienced overall, like nobody goes into detail to try to understand the content. You'll see a lot of times their comments are simply, you know, 'blah blah blah', so but in this case [the virtual scenario], and because the questions popped up in the middle of it and even though they were non-punitive, but 'they were really there for us to think', and also what was really helpful, was that you had given us a template and that template was geared towards okay these questions I should be paying attention to, pay attention to detail, so they say when I'm ready to fill out my scenario I was able to answer those, so really it keeps you on your toes. It's not just like, you know, the activity where teacher is monitoring the virtual scenario and you go through it, it's locked and you're done. No, actually you have to pay attention so you can go back there and answer those, you know your scenario questions, then the template. In this case, it's more interactive in a virtual world and of course the contents were very comprehensive.

Convergence

In all three methods of data collection, the participants exhibited confidence in learning. The quantitative survey results were supported by the comments students made about their confidence in learning in both the worksheets and in the interviews (Table 19). Overall indications were that students felt the simulation was relevant and helped them in learning the course material, made them more confident, and some expressed how they would use their knowledge moving forward.

Table 19. Convergence Confidence in Learning

Quantitative Results	% Importance	% Satisfied	Supporting Qualitative Themes	Frequency (# of comments)
Self-Confidence in Learning	N/A	88.6	Confidence in Learning	>20 (88)

Theme 2: Self Efficacy and Transfer

It has already been noted in the self-confidence and learning theme that a relationship between self-confidence in learning and self-confidence in clinical decision making was present in this study. The two survey questions that were positively reported in the survey and then supported in the reflection questions and interviews provided a basis for the development of the self-efficacy and transfer theme. This theme served to analyze the connection between the confidence in learning and confidence in the transference of knowledge to the clinical environment since the students in this study indicated that their confidence (self-beliefs) were associated with their perceived confidence to transfer their learning to clinical practice. Twelve students made 44 references to confidence in making critical decisions in real practice.

Self-efficacy in this study is described as the participants' confidence in making appropriate decisions in a virtual environment that led to their confidence in their ability to transfer these skills to real-world practice. As mentioned in Chapter 2, in healthcare simulation activities it was found that self-efficacy correlated to transfer of learning to clinical practice even though it was not clear what specific attributes of simulations resulted in the transfer. In this study, the qualitative data revealed control, deliberate practice, and relevancy as common attributes of the virtual simulation that affected the perceived self-efficacy and transfer of these specific participants.

Control

The perceived confidence participants' gained in their decision-making abilities was evident in discussions by the participants about their ability to have control in the virtual environment. As an example, several participants from both the worksheet data and the interviews referred to the opportunities in the scenarios to identify critical pathology. This is an important objective of these scenarios as imaging technologists are often the first healthcare providers to discover life-threatening pathology while scanning patients. For each of the patients in the scenarios, students were asked to make decisions about critical pathology they were viewing on CT and MRI images and whether they should expedite patient care based on what they were seeing. The following participants alluded to their self-efficacy by referring to these opportunities.

> [Role: Referring to scaffolding, diminishing help and increasing responsibilities]
> Jennifer: For the CT one, I remember that one a little bit more just because it was different like it, it, we did the exams but then it also brought in the missing or the guy that was looking for information and swallowed his flash drive. I remember that one and then the exams that we did I think having those other techs [characters in the scenario] that weren't around and making her, or I guess, me, do the exam by ourselves really helped. I liked that we kind of had to read through everything and do it ourselves and it gives us a better about idea about like what it would be like in real life.
>
> Student worksheet: “The 2nd scenario was the most confusing because I have only done one CTA scan ever. I see more head or brain scans than anything and identifying thorax anatomy is a little more difficult for me. I didn’t know where to place the bolus tracker or how to identify the three pathologies [dissection, pulmonary embolism, aneurysm] that are life threatening and now I feel I would be able to save someone’s life if I were in that situation.”
>
> Student worksheet: “I mostly learned how to visually identify SAH, SDH and EDH, IAH or areas of ischemia on CT images. I work in IR and do neurointerventional cases. Sometimes I look at CT images beforehand, but am not really knowledgeable at what I am looking at. This helped me to better understand what I may see on some of these images. This would be especially true for intracranial hemorrhage or ischemia, as these are STAT cases that we need to intervene on.”

Deliberate Practice

Self-efficacy also emerged from conversations about participants’ abilities to explore their decision making processes through non-punitive repetitive practice and the realistic nature of those decisions. Some of the most notable examples are provided below.

> Student worksheet: “I enjoyed this observation because it gave me the opportunity to make mistakes without actually putting a patient or coworkers at risk from a lack of understanding of MRI and all the things that are included with it. Another reason I enjoyed this experience was the fact that I truly believe that these scenarios are ones that real MRI techs have to deal with on a daily basis”.

> Student worksheet: “I did enjoy the virtual scenario. I appreciated the fact that I was able to explore what the consequences of what an incorrect decision would involve. Also, that it made me more aware of how the non-compliance or non-awareness would/could directly impact the patient or others’ lives” [intrinsic feedback].

> Interviewer: How do you feel about learning with the scenarios, or with actual patients, or in a laboratory-type environment?
> Owena: um I think initially learning with a virtual world be best for me just getting like more comfortable with it to where I felt more comfortable with patients, but I also, whenever I get to a point where I'm comfortable with something I need to do it hands-on to where I am with an actual patient. So, um, it's more realistic, if that makes sense, like the virtual scenario helped, definitely would, it helped me feel more comfortable in doing something like that, but then once I felt comfortable in that, I could, I think I'd be better with an actual patient.

> Interviewer: What type of learning would you feel more confident with before you begin working with patients on your own?
> Jesse: Yeah, yeah, I think it's a combination of all but I would really really appreciate in the virtual scenarios first, to begin with and really get a hang of a thing and even even [sic] you know performing it like acting um in a real-world to like learn from virtual scenario, walk through those things, understand that concept, and then go back and really act out it and then go to the real world and then uh I think by that time students will be ready

<u>Relevance</u>

Other participants discussed the relevancy of the activity and how it contributed to their self-efficacy. They indicated they felt they could now succeed in specific situations applying their skills to real-world decisions.

Elizabeth: I liked it, I felt that I would need a virtual experience before sometimes before going on to a real patient. I feel like it helps a lot to get that experience because it felt really real and all the information was there as if I really did have a patient so now that I would go out there into the real world I feel like it would build my confidence up a little bit more than just reading a book and you know going straight to a patient so right.

Interviewer: Can you talk about the benefits you've gained from your virtual simulation experience?
Rachel: I gained confidence in the clinical skills that I already had in MRI. I think I learned a lot about the things that could go wrong, and I remember like the whole time through the scenario, thinking like how cool it would have been to have this prior to doing MRI. I think it was very helpful and made me like more confident in the way I perform my job.

[From the perspective of a clinical instructor who is a veteran in CT]

Interviewer: So do you think if you were a student fresh out of school you would be confident in taking care of patients after this scenario?
Daniel: After this scenario, I think that this is a good start this is a good base. You know what, but this is going to give you that familiarization that you need. But I'm a big advocate in doing it in person. In having somebody, you know having a preceptor for a limited amount of time this is this is really good because this is going to build the foundation. However, I'm a big advocate in actually having a preceptor. You're working with this individual for a certain length of time until your competencies are signed off and that till I can visually make sure that you can do what is requested in the job title. I train people all the time all the time. I've trained so many people that pass a registry. Yeah, I just that's why I feel like that part of becoming an instructor is that I know what to tell them to study. I know that the exam is half anatomy. Know your cross-sectional anatomy. Know the physics. Know everything. But this, everything you have here, I think is a solid foundation. As far as just solely on this, and then just letting them loose in the work field, you and I both know that you know what I mean this is gonna this is good and you probably you probably can have a student just review this and go in there and take care of your patient providing they they really studied this. They would have a general understanding on how to go in there. It's just me in my personal opinion, I feel like you know you this is a good foundation, but you need to do it in person and I need to make sure that I see you do it.

<u>Convergence</u>

Participants indicated in the worksheets and in the interviews that the simulation improved their perceptions of self-efficacy which, in effect, improved their perceived confidence to transfer their learning to clinical practice (Table 20). The most common elements of this virtual scenario-based simulation that participants felt increased their self-efficacy and willingness to transfer were the control they were given over their own learning, the tenets of deliberate practice, and the relevancy of the activity.

Table 20. Convergence Self-efficacy & Transfer

Quantitative Results	% Importance	% Satisfied	Supporting Qualitative Themes	Frequency (# of comments)
Confidence in Clinical Decision Making	N/A	96.4	Self-Efficacy & Transfer	>20 (42)

Summary

In summary, Chapter 4 described the characteristics of the participants in this mixed methods case study and their interactions with the virtual scenario-based branching simulation. Six themes of objectives and scenario resources, feedback and support, problem-solving, fidelity (realism), perceived usefulness, and engagement and immersion described how the design characteristics of the intervention impacted participants' satisfaction, which supports the first research question. Students responded positively to the way the objectives and scenario resources were integrated, the integration and types of feedback they received (intrinsic, instructional, and supporting), the opportunities to problem-solve in the simulation, the level of realism that enabled them to relate the simulation to real-life experiences, the usefulness of the activity to both their learning and their clinical practice, and the level of satisfaction achieved through the engagement and immersion they experienced. These were explored through an evaluation of the survey and by recounting learner experiences through course artifacts and semi-structured interviews.

Two additional themes, that supported research question two, provided evidence that the design of the virtual scenario-based branching simulation was relevant and improved radiology students' confidence in their ability to make appropriate decisions in real-world practice. Students responded positively when describing the confidence they achieved with learning in the virtual space as well as making critical decisions in the virtual environment. The students also described their perceived confidence in applying their learning to the actual clinical environment with real patients. They indicated that the control they were given, the ability to repeat and reflect using the deliberate practice framework, and the relevance of the activity to their learning and to the clinical environment were all instrumental in building their confidence. These too were explored through an evaluation of the survey and by recounting learner experiences through course artifacts and semi-structured interviews.

The analysis and triangulation of the multiple types of data allowed the researcher to draw conclusions related to the research questions, as described in the following discussions. Additionally, the evaluation of the data generated limitations and recommendations for future research, which will be presented in Chapter 5.

Discussion Research Question 1- Impact of Design

Adult learners as described by Knowles (1985) are "autonomous, experience-laden, goal-seeking, now-orientated, problem-centered individuals". In this study, it was found that to satisfy these adult learners these characteristics should be considered in the design and implementation of the innovative educational experience. The results from the memoing, the survey, and the qualitative data in this study described six distinct themes that contributed to the conclusions about how the design elements of this virtual scenario-based branching simulation impacted the satisfaction of these adult students with the learning experience.

Elements of the design that both encouraged self-directed learning, and challenged the students' problem-solving skills, and, that were most noted by the students to be important to their satisfaction with their learning experience were the objectives, scenario resources, feedback, realism, engagement, and perceived usefulness. Notably, all of these elements supported underlying motivations for students to interact with the activity, and, the students often positively referred to how each of the design elements either encouraged them to self-direct their own learning or encouraged them to practice their problem-solving skills. Positive comments were also focused on the relevance of the activity to the students' current or future practice (Table 21).

Table 21. Perceived Impact of Students' Experiences

Theme	Sub-themes	Quantitative Data	Impact				
Research Question 1		N=57					
Theme 1 Objectives & Scenario Resources		Objectives and Information Satisfaction with Current Learning	Satisfaction	Self-directed Learning	Problem-based Learning	Critical Thinking	Confidence
Theme 2 Feedback & Support	Intrinsic, Instructional, Supporting	Support Feedback/Guided Reflection Satisfaction with Current Learning	Satisfaction	Self-directed Learning	Problem-based Learning	Critical Thinking	Confidence
Theme 3 Problem-solving	Identifying and analyzing problems, Resource gathering, An appropriate level of difficulty	Problem Solving Satisfaction with Current Learning	Satisfaction	Self-directed Learning	Problem-based Learning	Critical Thinking	Confidence
Theme 4 Fidelity (Realism)		Fidelity (Realism) Satisfaction with Current Learning	Satisfaction	Self-directed Learning	Problem-based Learning		Confidence
Theme 5 Perceived Usefulness	Application to future and current practice, Enhancement of online learning, Retention of learned information, Desire to use similar activities as a learning method for other courses in their program of study	Satisfaction with Current Learning	Satisfaction	Self-directed Learning			Confidence
Theme 6 Engagement & Immersion	Excitement, Feelings of poetic justice, Inner conflict about the antagonist, and Humor	Satisfaction with Current Learning	Satisfaction	Self-directed Learning	Problem-based Learning		Confidence
Research Question 2		N=57					
Theme 1 Confidence in Learning	Control Deliberate practice Relevance	Self-confidence in Learning	Satisfaction	Self-directed Learning	Problem-based Learning	Critical Thinking	Confidence
Theme 2 Self-Efficacy and Transfer	Control Deliberate practice Relevance	Self-confidence in Learning	Satisfaction	Self-directed Learning	Problem-based Learning	Critical Thinking	Confidence

Self-directed Learning

Perceived benefit in this study centered on the ability of the students to self-direct their own learning. In an online independent activity, it is vital for students to become self-directed in order for effective learning to occur. However, not all students have been shown or know how to direct their own learning. Looking back to the IOM's research, encouraging students to become self-directed learners could increase the knowledge level and the cognitive levels of entering healthcare providers. Retrospectively, the design of this activity was closely guided by the recommendations in the research for assisting students in learning how to self-direct while also engaging in learning the concepts for the respective course. The positive impact this design aspect had on satisfaction with these particular students was evident in the survey responses and in the discussions about several design elements. The impact this had on this study was twofold in that not only did the encouragement of self-directed learning promote satisfaction with this group of students, but it also provided educators with an avenue for inspiring lifelong learning skills.

The design elements that were integrated into the design-that align with Knowles (1975) elements of self-directed learning were; clearly defined objectives, accompanying resources, feedback, and non-punitive repetition and reflection. These specific characteristics were found to be important to the students and were also found to be determining factors in their overall satisfaction.

Objectives and scenario resources

Knowles (1975) emphasized that in order for self-directed learning to take place the learner must be given the ability to take control of his or her own learning through continued diagnosis of his or her own learning requirements, and that he or she should be given an opportunity to identify which resources are needed for their learning. Based on the data collected, the students in this study appreciated that the objectives and scenario resources combined with an open format allowed them to tailor their learning to their individual learning needs. Constructive references by the students were made to the benefits of knowing what desired actions would be practiced in the virtual scenario-based simulation, and how clear guidelines and resources assisted them in successful navigation and completion, such as suggestions for prior learning, artifacts that may be needed within the virtual scenario-based simulation, and guided instruction if needed.

The significance of this design characteristic was far-reaching as it not only prepared the students both physically and intellectually for the activity, but it also gave learners the opportunity to choose how they would continue to direct their own learning within the virtual scenario-based simulation based on their own learning needs and professional skill levels. It was evident from the results that the students, regardless of their expertise, found benefit from the activity because they decided what they would need to learn and how they would approach the learning. For example, from the semi-structured interviews, entry-level learners stated how they were able to expand their didactic learning by applying what they were currently learning in the course, and learners who were already proficient in the modality described how they would be using the applied information to improve upon their current clinical skills. The satisfaction the students gained from the ability to guide their own learning based on the open integration of the objectives and scenario resources was confirmation that self-directed learning was encouraged and practiced.

Feedback, Repetition, Reflection

Similar to the objectives and scenario resources, the feedback in this study also encouraged self-directed learning. Although the objectives and scenario resources provided a map from which students could plan their own learning, the immediate feedback in the virtual scenario-based simulation allowed the learners to engage in another level of self-directed learning in which they were able to explore how each answer could change the outcomes of the situations. This is unique in a simulation activity or scenario activity as the digital platform allowed for feedback to be provided immediately and as needed so the learner could immediately review, reset, and repeat, based on his or her own measure of time that was needed to regroup. There was no need to wait for a debriefing or another actual simulation day to make a better decision. The students in this study responded positively to this and it was found that their interactions were expanded exponentially.

The increased interactions were evident through the discussions from students about their appreciation to explore the consequences of both correct and incorrect decisions. Many described how the non-punitive aspect of the design along with the unexpected consequences of each choice motivated them to seek out knowledge that could be gained from knowing what ‘could’ happen if an incorrect decision was made. Students indicated they felt ‘safe’ in this environment to practice skills that would otherwise be unknown to them, such as actions they should take if an incorrect choice were inadvertently made with an actual patient. As such, students promoted their own learning by exploring multiple answer choices in order to explore the feedback for each situation, thus promoting their cognitive engagement, which was similar to outcomes found in simulation and scenario design research (Cook et al., 2010; Cook et al., 2013; Okuda et al., 2009; McGaghie et al., 2010). Students who engaged in this exploration indicated they felt they were able to advance their knowledge beyond the intended objectives and goals of the course modules. This self-direction to expand their knowledge was further enhanced through the encouragement of problem-based learning.

Problem-based Learning

As previously described, problem-based learning is an active learning strategy also recommended in the literature by several organizations as a way to enhance the cognitive skills of learners in an attempt to mitigate medical errors (ACICBL, 2011; IOM, 1999; IOM, 2003; Martino & Odle, 2008). Problem-based learning was supported in this case study through the use of scenario-based learning provided in context using a branching case progression in a virtual simulation.

A component of PBL is the act of problem-solving which was an element of the design students found to be important in the virtual scenario-based simulation. Neufeld and Barrows (1974) suggested that problem-solving invokes both self-directed learning and metacognitive skills. Likewise, many of the same agreeable design attributes that encouraged self-directed learning in this study also appeared to encourage problem-based learning. These included an open format and learner control, accompanying resources, feedback, non-punitive repetition and reflection, and realism.

The tenets of PBL learning described by Neufeld and Barrows (1974) that were satisfied in this virtual scenario-based simulation included opportunities for the learner to identify and analyze a problem, opportunities to search for resources to solve the problem, produce a solution, critically appraise the solution, and engage in self-assessment. These were identified in the student interviews and worksheets in the students' descriptions of how they approached the problems they encountered. There were multiple illustrations of resource gathering that they used to solve the problems, and, once they produced their solutions, they described how they were able to analyze their decisions through the exploration of the different forms of feedback.

The ability to take control of his or her own learning by challenging themselves was also evident in discussions about how they approached problem-solving activities. An interesting finding was that students indicated that some of the problems were challenging, however, they continued to work through them even though they could have easily skipped them and moved on in the story. Their underlying motivations for this were not entirely clear, however, some elements of the design may have been contributing factors.

One observation was that even though there were no extrinsic rewards and no penalties related to the problem-solving activities, the incentive for completing challenging problems appeared to rely heavily on the perceptions of worth of the activity by the learner. A closer look at the student's comments showed the students' desires to continue to problem-solve cognitively demanding experiences were closely related to intrinsically motivating design attributes that were prevalent in this study, such as accomplishment, relevance, and engagement.

One theory is the effects of scaffolding. Scaffolding was a design characteristic that was used to invite a sense of accomplishment by preventing cognitive overload. As previously described, scaffolding was interjected into the design of both the content and the resources to reduce cognitive load for students as they worked through the problems.

Even though this was suggested from research on simulation and scenario design (Clark & Mayer, 2013; Ke, 2016; Reedy, 2015), only a few of the students openly indicated this was a determining factor in their willingness, and maybe ability, to pursue solutions to the problem-solving activities. However, the ‘lack’ of comments about becoming overwhelmed, may provide a better picture of the effects of this characteristic. First, it was not overly evident in the student comments that students were ever overwhelmed with the activity. Second, observations of the completion rates in the LMS were at 100%, concluding that all of the students were able to fully accomplish the activity. Last, only two students voiced their uneasiness with the increasing demands of each scenario day. This may suggest that the scaffold design was beneficial in reducing most students’ cognitive load, therefore allowing them to be able to challenge themselves with the activities.

Yet, even though scaffolding may or may not have been an underlying contributor, the driving forces for the students’ persistence to engage in problem-solving appeared to center on the multitude of comments students made about relevance and engagement. Overall, the students expressed that they felt the virtual scenario-based simulation was relevant to them in their learning and their future practice, which is supported by Knowles’s (1980) adult learning theory in that adults find relevance through problem-oriented learning which they can immediately apply to their workplace. Likewise, relevant content was listed as a best practice for simulation design, scenario design, and high-reliability scenario design (Okuda et al., 2009; Salas et al., 2005; Schank et al. 1999). It was also found that the relevance of this activity to the students was closely related to the design of the simulation to emulate a real-world environment.

Participants identified realism as overwhelmingly important to their satisfaction with the learning activity.

Realism

It was apparent in the results of this study that many of the students' perceptions of the scenario very closely resembled that of a relatable situation. In this context, with these students, the level of realism afforded through the character personas, the CT and MRI exams, the artifacts that refer to real-life procedures and protocols, related examples of actual real-life events, the storyline, and a content-valid design that was developed and reviewed by content experts was perceived by the students to be effective in creating a 'realistic' and 'relatable' scenario in which to practice their skills.

More specifically, the backdrop, the delivery of the dialogue in a text based format, and the caricatures were indicated to be satisfactory, however, more detailed discussions occurred about the attributes of realism the students could relate to, such as the validity of the content, the realistic scans, and the realistic storyline. Many students commented on how they were able to relate to the experience and how they were able to intertwine their own real-life experiences. Therefore, it is evident from this study that it is possible that the level of realism that can be afforded in an educational virtual scenario-based simulation can be similar enough to an actual environment to provide situated learning. The positive effect this had on these particular learners may be attributed to the characteristics of an adult learner as described by Knowles (1980). In his adult learning theory, Knowles (1980) posited that adults bring with them their own experiences as a foundation for new learning and that being able to make connections and perceive relevance is important in their learning. This was evident in the results as the intention to apply new knowledge to real-world practice was referenced by many of the students.

In addition to relevance, several students pointed out that they were motivated to continue to problem-solve to see how their decisions affected the characters in the story. This may be closely related to each student's intrinsic motivation to learn, however, from the results it was evident that these particular students were also motivated by their enjoyment with the storyline.

Affect

As contextual learning was the basis for the design of the virtual scenario-based simulation in this study, the strategies for developing the learning environment that was seen to produce positive reactions by the students required further examination during the analyses of the study. It was apparent that the storyline and the role the students donned while in the environment were important to the satisfaction students gained from this learning experience.

The use of a story in which the student becomes a participant invoked many emotional responses from the students that were surprising. Excitement, feelings of poetic justice, inner conflict with the antagonist, and humor were a few that were reported by a greater number of the students. All of these emotions suggest the students became situated within the environment. The theory of situated learning suggests students are more likely to learn by actively participating in their learning domain as compared to passive learning. Additionally, in many of the students' descriptions of their involvement, it was apparent the branching design in which they were able to choose the direction of the story highly affected their engagement. Not only were they participants, but they were participants who could interact with the virtual technologists, patients, and family members to change the outcomes of the scenes, which was persistent in their comments.

The humor that emerged was also suggestive of increased involvement. There were many descriptions of students having fun and many displayed their own humor in their comments. This suggests the design of the activity was not too cognitively demanding. However, psychologically, humor is used by many healthcare professionals as a coping mechanism where one is confronted with urgency, tragedy, and emotional stress multiple times a day. This suggests a deeper level of engagement with the story, particularly when the students took their humor a step further and engaged in gallows humor. Gallows humor is humor that treats the serious, frightening, or painful subject matter in a light or satirical way. Although deemed inappropriate by some, it is used as a strong coping mechanism for health care workers (Rowe & Regehr, 2010; Watson, 2011). When students referred to the antagonist getting what they deserved or when they referred to their enjoyment that the antagonist was injured suggests that the students were immersed to the point that they began to use their clinical coping mechanisms to deal with the increasing demands and increasing emotions they encountered within the simulated environment.

Becoming situated in the context in a virtual world has become a massive enterprise for the gaming industry, which, if capitalized on for the purpose of online education for professional programs, may provide an avenue of learning that far surpasses traditional methods of educational delivery. In this study, the industries of gaming and education can be intertwined based on the students’ reactions and reflections about the activity. A great number of the students’ degree of attention and passion that emerged from the qualitative discussions not only supported previous discussions about student satisfaction with specific design elements and the relevance of the activity, but their enthusiasm also implied a level of engagement that can be likened to flow and immersion that is most often described in game-based research.

Although a dedicated study would be needed to confirm flow was actually achieved for any of the individual participants, the discussions produced many elements of flow that alluded to at least an intense level of engagement. Csikszentmihalyi (1990) described the elements of flow in which there is a balance between the demands of an activity and the skills of the individual; there is a merging of action and awareness; there are clear goals about what one is going to do; there is immediate and unambiguous feedback; there is an intense focus and concentration on the task; there is a perceived control over the activity; there is a loss of self-reflection; there is a distorted perception of time; and the activity is intrinsically motivating. The students' responses were a culmination of all of these elements.

It should be noted that a loss of self-reflection may not be desirable from a learning perspective, however, the integration of the worksheet in which students developed a concept map and in which they were challenged to reflect about their experiences, provided a way for the students to bring the experience back into focus. The students indicated this was an important aspect of the activity. Also, as described in the literature review, reflection is a major component of the deliberate practice framework that provides a way for healthcare students to build their higher-order thinking skills and metacognitive skills (McGaghie et al., 2010; Schraw & Moshman, 1995). It was also said that the development of one's metacognitive skills is an important step in becoming self-directed and also in clinical decision-making abilities.

The culmination of design strategies for the virtual scenario-based simulation provided satisfaction with the learning experience for this group of students through the ability to self-direct and problem solve in a realistic and engaging environment. The impact of the design, however, was not only significant to the students' satisfaction with the learning experience it also enhanced the student's confidence in their decision-making abilities within the learning experience (Table 21). For many of the students, this led to their perceived confidence in transferring their new knowledge to clinical practice.

Discussion Research Question 2-Confidence

"For the group of advanced imaging radiology students in this case study, how does a virtual scenario-based branching simulation impact the students' confidences in their ability to make appropriate decisions in real-world practice?"

Improving the higher-order thinking skills of healthcare students and professionals was a recommendation in the literature to address medical errors (Facione & Facione, 2008). Applying domain-specific knowledge with efficiency and accuracy in a situated context requires higher levels of thinking which is critical when making life-altering decisions in an environment that is constantly changing. As previously noted by James (2013) and Stark and Fins (2014) errors of omission in which the professional failed to act when he or she should have, and errors of commission in which the professional acted incorrectly was suggested by many to be caused from a lack of high order thinking and metacognitive skills of the healthcare professionals. As previously described critical thinking is a purposeful, self-regulatory, nonlinear, and recursive cognitive process that a person uses to make a decision about what to do in a given context (Facione, 1990, p.3), and since virtual branching simulations have been described as a problem-solving strategy that encourages the critical thinking and decision-making skills of the learner (Gordon, 2009; Smith et al., 2014; Talbot et al., 2012), this study focused on encouraging higher-order thinking through problem-based learning, critical thinking, and decision making strategies in the virtual environment.

Confidence in Learning

The first theme that emerged from the data was Confidence in Learning, which describes the confidence students gained in their decision-making in the simulation. The results indicated that within the virtual scenario-based simulation itself confidence in learning was overwhelmingly positive for all of the interview participants and nearly all of the survey participants.

Multiple facets of the scenario-based simulation design that improved satisfaction with this group of students' learning experience were also indicators of how the students developed confidence in their clinical decision-making abilities over the course of the simulation. The survey indicated the students were extremely confident in learning with the scenario, and the qualitative data revealed that much of their confidence was based on their ability to self-direct through the control they had over the story, the access they had to an appropriate number of related resources, the relevance of the scenes to their current and future practice, the opportunities for repetition and reflection, and self-assessment through feedback that was constructive, non-punitive, and motivating.

Several students indicated that having the ability to choose what they would learn, and how they would approach their learning through non-punitive repetition, reflection, and engagement gave them the confidence to explore the multiple outcomes of their decisions. They also expressed that the ability to problem-solve within a 'safe' environment was important in building their confidence and that a sense of accomplishment was gained from becoming an active participant in the story. The confidence this group of students gained with the learning activity was also evident in some of their discussions about the activity emulating an actual clinical rotation and also discussions about feeling prepared for the clinical environment. It was evident that their confidence in making decisions in the virtual environment was a determining factor in several of the students' declarations of perceived confidence in applying their knowledge in a real environment.

Self-efficacy and Transfer

The theme, Self-efficacy and Transfer, describes the participants' perceptions of their confidence in their ability to apply their knowledge in clinical practice. The ability of the simulation to provide a level of confidence that would result in the student's perceived confidence in applying their decision-making skills to clinical practice was realized with a majority of the survey participants and most of the interview participants in this study. Varying levels of pre-course knowledge and experiences may have been a determining factor in how far the students were able to increase their confidence levels as experience in the field ranged from 1-21+ years. It was apparent that for some of the less experienced students the level of confidence was limited to confidence in entering the real environment for learning and not necessarily for performing the duties of an advanced level technologist. Thus, the scenario-based simulation was variable enough in levels of complexity to provide benefit for varying levels of experience.

The results in this theme can best be described by Bandura's (1982) definition of perceived self-efficacy, stating that self-efficacy is not about one's abilities or skills, but, rather, " it is concerned with [one's personal] judgments of how well one can execute courses of action required to deal with prospective situations" (p.122). In the context of this study, self-efficacy is described as the participants' confidence in making appropriate decisions in a virtual environment that led to their confidence in their ability to transfer these skills to real-world practice. An improvement in self-efficacy can be suggestive of improving the cognition, motivation, and affect of these students as Zimmerman (1995) stated that self-beliefs have an effect on these self-regulatory processes. These particular students verified growth in their knowledge, and were motivated and emotionally charged in the recounts of their virtual experiences.

Bandura (1977) stated that one of the sources in which self-efficacy beliefs are derived are performance accomplishments. Performance accomplishments were satisfied by using the deliberate practice framework in this study. Deliberate practice enabled the students to engage in self-directed forms of practice that were challenging and allowed the students to acquire a sense of accomplishment that led to increases in self-efficacy. This is similar to the positive results McGaghie et al., (2010) found in medical simulations. This is also supported by Bandura's (1977) observations that if a student encounters regular failure, especially in the early learning process, the self-efficacy of the student may decrease, and likewise, if a student encounters increased numbers of successes, then self-efficacy is strengthened. He also noted that with increased self-efficacy it is possible for the student to generalize to other situations (Bandura, 1977), for example, varying patient encounters in clinical practice. This is an important concept in the learning and transference for healthcare students as a failure to act in an emergent situation may cause harm. To provide a similar example, Bandura (1977) contrasted efficacy expectations with response-outcome expectancies. He found that even though an individual may believe that a certain action will produce a desired outcome if they do not believe that they themselves can perform that action then they may fail to respond at all (Bandura, 1977).

The elements of the design of the virtual scenario-based simulation also revealed control and relevancy as attributes of the virtual scenario-based simulation that positively influenced the perceived self-efficacy and transfer of these students. Similarly, learner control was an important aspect of self-efficacy and transfer in Gegenfurtner et al.'s (2014) study of digital simulations. The students in this study felt that their ability to have control in the virtual environment enabled them with opportunities to engage in repeated practice of the skills they felt were important to their learning. This allowed them to acquire a sense of accomplishment for the concepts they felt were relevant to their own learning and clinical expertise.

It was evident in the students' responses to both the survey questions and the qualitative data that the satisfaction the students gained from the design of the activity enabled them to become comfortable with learning in the virtual environment. It was also clear that the confidence they gained within the virtual simulation led to many of the student's perceptions of confidence in their actual clinical decision-making abilities. Although a simulated environment cannot replace actual hands-on learning for these students, it did provide an avenue for safe repetitious practice before entering the clinical environment.

CHAPTER 5: CONCLUSIONS

Providing advanced education in radiologic sciences addresses the need for building technologists' skills beyond their primary education levels. The problem in this study was predicated on the increasing risk of harm for patients and providers that may be mitigated with advanced education. The problem in this study related to the exploration of an innovative teaching method that will aid in current and future demands in radiology. This study has many implications for educators, students, and ultimately for the patients who will be under their care.

Increased expectations of healthcare educators to address safety concerns surrounding medical mistakes in the US has been a continuing topic since the IOM's publication of "To Err is Human" in 1999. It was then when professional organizations, accrediting bodies, and educational institutions began investigating ways to improve outcomes for patients. One such investigation was through changes in the way educators approached the instructional delivery in their professional programs. Developing innovative teaching practices, such as the one in this study, that would foster life-long learning, and that would encourage students and professionals to become self-directed learners were suggested in order to maintain the fast pace of ongoing medical knowledge and technology. In addition, it was recommended that healthcare educators encourage a higher level of thinking in their students that would enable the healthcare professional to make sound clinical decisions while caring for patients. Furthermore, many of these organizations encouraged educators to exploit current educational technologies as a way to quickly disseminate knowledge and to enhance teaching practices. In the determination to mitigate medical errors the use of innovative teaching has been investigated in order to assist students and professionals to stay current in their practice and to develop a higher level of thinking. According to Sullivan (2005), "The challenge for professional education is how to teach the complex ensemble of analytical thinking, skillful practice, and wise judgment upon which each profession rests" (p.195).

This mixed methods case study sought to discover how students in advanced modality courses in a radiologic sciences online program were impacted by the introduction of a virtual scenario-based simulation that aimed to provide satisfaction in their learning and to provide confidence in their current learning that would transfer to clinical practice. The ultimate goal was to provide this population of students a learning activity which challenged them yet provided a desirable learning environment. More far-reaching, this study was also expected to provide guidance for the design and implementation of virtual scenario-based simulations in an allied healthcare context. The research was guided by the following two research questions.

1. For the group of advanced imaging radiology students in this case study, how does the design of the virtual scenario-based branching simulation impact the students' satisfaction with the learning experience?
2. For the group of advanced imaging radiology students in this case study, how does a virtual scenario-based branching simulation impact the students' confidences in their ability to make appropriate decisions in real-world practice?

As explained in Chapter 3, this study was a case study using mixed methods to provide an in-depth and pragmatic exploration of context and behavior of this particularly unique population. The study relied on both quantitative and qualitative aspects of the phenomena that were obtained in a concurrent design. For the quantitative data, an online anonymous survey was conducted after students completed the simulation experience. For the qualitative data, the researcher analyzed a course assignment in which the students mapped learned concepts and then reflected about the material and the experience. The researcher also conducted semi-structured interviews with 11 participants after the simulation experience.

This chapter presents the conclusions, recommendations for future design and implementation, implications, and recommendations for future research. This dissertation also provides support for virtual scenario-based simulations as a method to enhance online learning in an allied healthcare context.

Conclusions

The ability to perform in a profession in which higher-order thinking is required to make sound clinical decisions for the health and well-being of another person requires careful consideration for the development of educational tools that will foster those skills within the students.

This mixed methods case study brought together both quantitative data and supporting qualitative data showed how the virtual scenario-based simulation affected this particular group of students, and how the design may be used for future development. The analysis of the quantitative data provided a clear picture of how this virtual simulation was positively perceived in both satisfaction and in confidence with the students’ overall learning experience. The qualitative data provided depth and meaning to the quantitative findings by providing reasons for the students' satisfaction and confidence.

Both research questions in this study provided insight into how the design and implementation of a virtual scenario-based simulation could be beneficial in the education of online radiology program students who are in advanced imaging courses. The virtual scenario-based simulation innovation in this study was shown to encourage students to engage in self-directed learning and in higher levels of thinking that would support them in making sound clinical decisions while caring for patients. Additionally, it was evident in the students' responses to both the survey questions and the qualitative data that the satisfaction the students gained from the design of the activity enabled them to become comfortable with learning in this virtual environment. Becoming comfortable and satisfied motivated these students to engage in learning and in building their confidence in applying their learned knowledge. It was clear that the confidence they gained within the virtual simulation led to many of the student's perceptions of confidence in their actual clinical decision-making abilities. Confidence in actual practice empowers students to perform when needed which is vital when they will be faced with life altering decisions.

Based on the results of this study, the researcher advocates for the use of similar online experiences for professional program students. The opportunities afforded by a virtual scenario-based simulation that encourages self-directed learning, problem-based learning, and critical thinking in an engaging and realistic context enhances the online experience of the student and addresses the need for the encouragement of higher-order thinking to reduce the risk of medical errors for advanced imaging technologists.

Recommendations for Design and Implementation

As previously described, the instructional intervention design was a product of design characteristics borrowed from extensive research in scenario-based learning, simulation-based learning, and educational virtual environment research. As various renditions of virtual scenario-based simulations are slowly emerging in healthcare education they have not yet been explored in the context of radiologic sciences in educating students in advanced modality imaging.

Recommendations for future designs rely on multiple suggestions from the literature and from the results found within this study.

1. Branching design-As the story progressed in this scenario, the patient evolved with the learner's decisions requiring the learner to think critically and draw upon previous knowledge to make a decision about what should be done.
2. Goal-based scenario design-This design is similar to online games in that learners are motivated intrinsically through the achievement of a goal. Components of this design should include a goal, a realistic mission, a storyline, a role the student portrays, operations that align with the objectives, appropriate resources, and just in time feedback. In this study, it was found that the interjection of humor into the storyline was extremely important in both satisfaction and motivation.
3. Deliberate practice framework-This framework encourages the learner to develop higher-order thinking and metacognitive skills. The learner should be provided with opportunities for intense repetitive practice with immediate feedback and continuous reflection.

4. E-authoring software-Although the software used for this study, Articulate 360® was instrumental in designing a platform that was versatile and user-friendly, the designer should take into consideration the steep learning curve that may be encountered if one has little or no background in working with E-authoring software. Even with some background in working with this type of software the amount of time needed to fully develop a branching type scenario in a virtual environment was extensive.
5. Self-directed learning- This is encouraged by allowing the learner to take control of the activity and subsequently his or her own learning. In this study and in the literature this was accomplished by providing an open format (autonomy), clearly defined objectives, accompanying resources, immediate feedback, and loosely defined time constraints in which the learner may return to the activity as many times as needed allowing for non-punitive repetition and reflection.
6. Curriculum integration & Instructions for pre-learning-This provided the student with the background and domain-specific knowledge needed to be successful in the environment, thus increasing the likelihood of improved self-efficacy and transfer. Carefully integrating the activity into the curriculum by aligning the activity with the objectives was an important consideration in the simulation and scenario-based literature.
7. Guidance, Instruction, and Objectives- Clearly defined objectives, a set of instructions for navigation, and continuous content guidance provided in a scaffold design set the stage for successful independent self-directed learning.

8. Scenario Resources-These should be specific to the scenario-based simulation, relevant, and delivered as needed. A scaffolding approach to prevent cognitive overload was employed in this study and was suggested in the literature. In this study, an important type of resource students consistently referred to were mnemonics that aided the students in preventing error in a clinical situation (virtual and actual).
9. Trigger event-In this study the trigger event provided the learner with a reason why the content in the scenario was important for them to master. Actual medical error cases that had occurred were presented displaying a tragic or serious consequence of a sentinel event. These were directly related to the scenario the students were about to engage in.
10. Realism-The aspects of realism in relation to the validity of the content, the realistic scans, and the realistic storyline were important to the participants in this study. Realism enabled learners to connect their learning with their previous experiences.
11. Problem-solving –Providing varying levels of problems in the scenarios that allowed the students to identify and analyze problems encouraged students to practice building their higher-order thinking and metacognitive skills. The resources that were provided supported the students in attempting solutions and the multiple forms of feedback allowed them to appraise the outcomes of their solutions albeit in a virtual environment.
12. Immediate Feedback –The use of multiple forms of feedback that were non-punitive, instructional, intrinsic, and supporting engaged the students and

motivated them to explore the consequences of both positive and negative actions. In this study students consistently explored what could happen if a wrong decision was made and subsequently explored what they should if this does happen.

13. Repetition (unlimited) & Reflection (pre-planning, during, & post reflection)- The ability for the students to review their actions, reset the scenario, and repeat at their own measure of time and as many times as needed was shown to encourage self-directed learning and motivation. Also, providing an opportunity within the activity to journal what the students were experiencing was helpful in providing reflections about the concepts the students felt were important to them and how they were accomplishing their own learning.
14. Self-efficacy & transfer- learner control and relevant realistic scenarios improved the perceived self-efficacy and transfer of the students in this study. Performance accomplishments through deliberate practice were also indicators for improved self-efficacy.
15. Assessment –The use of formative assessment in the forms of participation and the completion of a concept map with reflections was instrumental in providing autonomy and encouraging exploration and self-direction in this study.
16. Storyline-The use of an engaging but serious storyline motivated the students to continue learning. Suspense and humor worked well with this group of students.

Although the recommendations for future development was comprised of elements that improved satisfaction and perceived confidence in clinical decision-making skills in this study with these participants, additional research is needed to further generalize the findings.

Implications

Online scenario-based learning for the development of critical thinking and problem-solving skills does have applicability beyond healthcare, so this study could be valuable to educational technology researchers who are studying virtual scenario-based simulations in other professions that deliver online education to develop these skills. It is expected the impact of this study will incite additional research on this innovative teaching strategy in radiology education research, healthcare research, online education research, simulation research, and educational technology research.

Future research

Given the complexity of this study in that the viability of a virtual scenario-based simulation has not been previously explored and that the educational innovation relied on the design and development of a product that would follow the curriculum of this unique population, this study would benefit from further research.

Future research focusing on actual clinical experiences following the introduction of the virtual scenario-based simulations would be beneficial in determining how the students' perceived confidences were either realized or not realized in the actual environment. This could be accomplished by performing a qualitative case study following a group of students over time through the professional CT program at MSU into clinical practice.

Another avenue for research would be to explore the effects of the virtual simulations for entry-level students who have not yet practiced independently in the field. As this study only included registered radiographers, subsequent mixed methods case studies using the same methods as this study should be conducted within the same university to evaluate the effects of the online curriculum for students who have had limited clinical experiences.

The perceived usefulness theme in this study foreshadows another dimension to this study that in itself could provide insight into the viability of this intervention; the technology acceptance model (TAM). The TAM model, typically seen in the IT industry, investigates and predicts the adoption of new technology using the constructs perceived usefulness, perceived ease of use, and behavioral intention to use (Park, 2009). The theories of temporal disassociation, focused immersion, heightened enjoyment, control, and curiosity that have been associated with previous TAM research (Agarwal & Karahanna, 2000; Saade´ & Bahli, 2005) have all been alluded to in the results of this investigation. In a larger sample, the use of structural equation modeling (SEM) could provide a closer investigation of the complex relationships between and among these different variables.

Another area that was unexplored in this study was the effect of multiple forms of media to increase the level of realism. One student mentioned that she would have preferred an auditory delivery of the dialogue and a couple of other students recommended an instructional video be introduced in the beginning. As already mentioned, the design for this study focused on the content and on only one form of delivery which was visual. The CT and MRI images, the pathology images, and the backgrounds were real, however, the dialogue remained in a text form rather than auditory or through a video. Research involving the cognitive affect model of learning with media may provide further insight, and a more in-depth analysis and correlation with serious games are suggested.

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APPENDIX A

Virtual Scenario Snapshots

Figure 3. **Example of a decision point within the scenario**

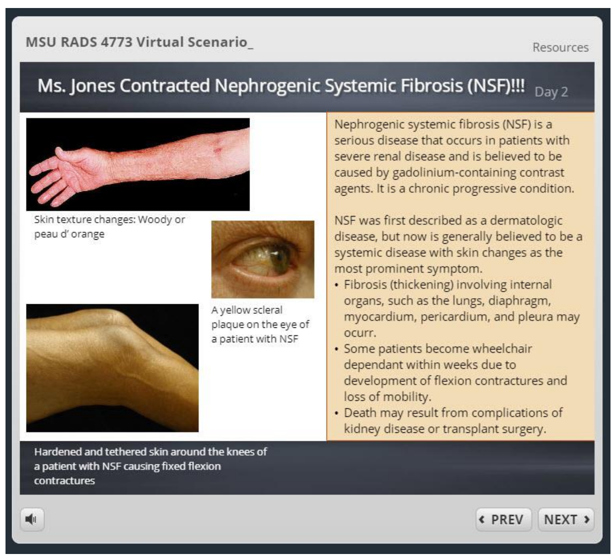

Figure 4. **Example of a consequence within the scenario**

Figure 5. Example of assessment within the scenario

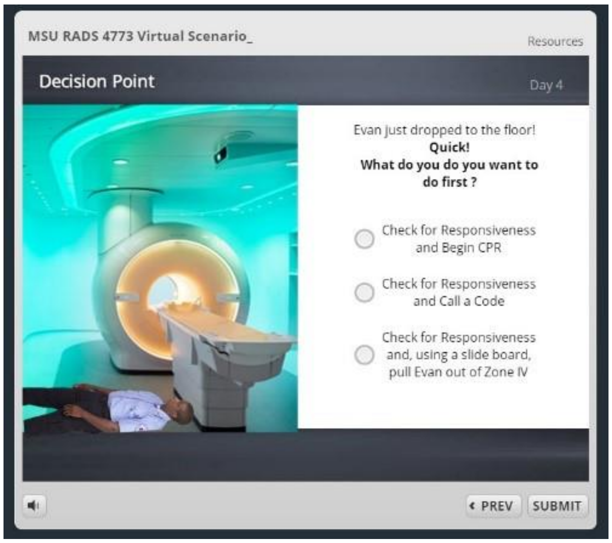

Figure 6. Example of a decision point within the scenario

APPENDIX B

Video Walk Through (example)

CT Virtual Scenario Simulations Walk Through

https://youtu.be/Qh-YH-ToyOA

APPENDIX C

Student Worksheet

MSU RADS 4703 – Principles of Computed Tomography

Virtual Scenario-based Simulation Worksheet

Instructions

Fill this worksheet out as you proceed through the three virtual scenarios.

At the end you will upload this worksheet into the dropbox. Your grade is a participation grade. Your grade will come from your completion of the scenarios and this worksheet.

Your completion is monitored in the scenarios, so you must complete all scenarios (they will be released in three different modules as they are each part of an ongoing story).

Make sure you fill in the table and answer the questions at the end of this worksheet.

Wait until the worksheet is complete before you submit anything. Turn it all in at once by the due date in the course schedule.

Tips

- It is best to have a wired internet connection so you do not drop out of the scenario due to a loss of internet. The scenarios will work on multiple devices, but be sure you read the procedure for getting back in if you get dropped out.
- If you lose your connection, or if you simply must finish later, you will just close the scenario AND the window in D2L. If you do not close the D2L window, you will get an error when you try to return. When you come back it will ask you if you would like to resume where you left off.
- You may go back as many times as you want. There are navigation buttons at the bottom. You are not penalized for mistakes or for roaming about.

Student name: ________________________ **Approximate time spent:** ________________________

Part 1 of 2-Concepts Learned

	Patient's name	Patient History	Patient's Pathology	List Procedures and Protocols	List mnemonic aids (memory aids) found in each scenario. Give a brief description of each.	List any hazards and/or conflicts identified for each scenario.	List the three most important things you learned in each scenario in order of importance.
1							
2							
3							

Part 2 of 2-Reflections

Answer the following questions regarding your experience. Substantial answers should be provided. Do not answer with one word answers.
1. Of the observed scenarios, which one was your favorite and why?
2. Which of the scenarios appeared to be the most complicated or confusing? Explain.
3. List the mnemonics or memory aids listed in the scenarios that will help you with your studying for the final or for the registry.
4. Describe what you learned from the experience that you did not already know or describe what helped you refresh your knowledge?
5. Did you enjoy your virtual observation experience? Why or why not?
6. List any technical problems you encountered with the scenarios.

APPENDIX D

Instructional Design Document (example)

Instructional Design Document

Kimberly Onstott

MRI Applications-Virtual Scenario-based Simulation

Project Summary

These scenarios are part of an undergraduate magnetic resonance imaging (MRI) course. They are intended for the students to experience practice with concepts they have already learned in the course. The students taking this course are members of a Bachelor's program who are either seeking to obtain their Bachelor of Science in Radiologic Sciences or who are attending the course in preparation to sit for the ARRT national MRI registry exam.

1. Front-end Analysis

Problem Analysis

A strong knowledge base in MRI concepts and MRI safety is needed by imaging professionals to safely and accurately perform MRI examinations for patients in their care.

It is unfortunate that many mistakes in the clinical environment have occurred because of a lack of knowledge or an inability to act in a timely manner. The aim of these scenarios is to provide deliberate practice to address these concerns in a safe environment.

Context Analysis

Description of Organization

Midwestern State University is a traditional university that typically caters to traditional on-campus students. However, in the college of health sciences, many of our students are either non-traditional working professionals returning to school to obtain additional degrees and training, or entry-level students that must travel to clinical sites in their final years of school to complete their practicums. All of these students must maintain their skills and status in their clinical environments, so distance education is highly sought after. Distance education has been an instrument of instruction for our health science college for many years.

Learner Analysis

General Demographics and Learner Characteristics

The learners who will be taking this course are working professionals who may also be enrolled in the Bachelor of Science in Radiologic Sciences program at MSU. Many of these individuals have been in the field for some time and are returning to complete their degrees.

Motivations

Magnetic Resonance Imaging is becoming one of the more widely used advanced imaging modalities for the diagnosis and treatment of patients in the United States. Radiographers who are registered in MRI are highly sought after, so technologists are eager to increase their status and income by becoming trained in MRI.

An important consideration in the education of MRI technologists involves the hazards surrounding this modality. Throughout the history of this modality, there have been many occurrences of injury and even fatalities related to the insufficient training of technologists and of other hospital staff. This activity is designed to reinforce course goals and course objectives that address the issues of safety in this modality.

Prior Knowledge

Learners must have completed a formal radiography program or they must be in their final semester of a formal radiography program before they can enroll in this course. Before beginning the scenario activity, learners should be familiar with cross-sectional anatomy, should have completed a significant portion of the MRI in Applications course (at least beyond module 5), and be proficient in health care provider basic life support knowledge.

Technical Skills

Regarding the online format, the students will have completed a significant amount of online work in the MRI Applications online course and will have completed several other online courses in the radiology programs, so no new technical skills are needed to navigate the online environment.

The students may not, however, be as familiar with this type of virtual activity. Depending on their skill set, some students may need initial guidance.

Abilities and Disabilities

The learners may already be quite familiar with most of the content in this course based on their current professional status or they may have been newly introduced to this material in this course. Based on the prerequisite courses alone, students should already have a basic understanding of advanced clinical practice skills, cross-sectional anatomy, and imaging pathology. Students who have not done well in the previous courses may be at a disadvantage coming into this course. The activity builds upon information already learned and combines the old knowledge with new MRI information.

Relevant Standards

The standards outlined by the American College of Radiology in the ACR Guidance Document on MR Safe Practices: 2013 for MRI safety for the treatment and diagnosis of patients is followed for this activity.

Learning Activity Goal

Drawing upon previous knowledge and newly learned information students will be encouraged to engage in self-directed learning, problem-solving, and critical thinking in MRI imaging by applying their knowledge in a simulated environment.

Activity Outcomes

1. Upon completion of this activity, students will demonstrate knowledge in making appropriate technical decisions surrounding MRI safety.
2. Upon completion of this activity, students will demonstrate knowledge in making appropriate ethical decisions surrounding MRI safety.
3. Upon completion of this activity, students will be able to identify external hazards in MRI.
4. Upon completion of this activity, students will be able to identify internal hazards in MRI
5. Upon completion of this activity, students will reflect on MRI safety knowledge.
6. Upon completion of this activity, students will demonstrate knowledge in patient care for MRI patients.

Initial Learning Objectives

Day 1: Patient Care, MRI Safety, and Brain Anatomy

- Apply communication skills with virtual patients in MRI
- Perform basic life support
- Recognize MRI safety zones and levels of personnel
- Make informed ethical decisions
- Research implanted medical devises
- Identify brain metastases
- Identify brain anatomy

Day 2: Patient Care, MRI Safety, Contrast Media, and MS Imaging

- Apply communication skills with virtual patients and colleagues in MRI
- Apply patient exam preparation skills with virtual patients in MRI
- Know MRI safety zones and levels of personnel
- Make informed ethical decisions
- Calculate and interpret GFR
- Identify contraindications for MRI contrast media-NSF
- Identify multiple sclerosis on MRI
- Identify specific MRI sequences for MS
- Identify external hazards

Day 3: Patient Care, MRI Safety, and Abdominopelvic Anatomy and Imaging

- Apply patient exam preparation skills with virtual patients in MRI
- Interpret SAR limits
- Identify thermogenic risks of RF power
- Reduce burn risks with protocol adjustments
- Make informed ethical decisions
- Identify symptoms of pancreatitis
- Identify abnormal pancreas pathology
- Know first aid for RF burns

Day 4: Patient Care, MRI Safety, and Cerebral Anatomy and Imaging

- Apply patient exam preparation skills with virtual patients in MRI
- Prevent external hazards
- Know first aid for projectiles
- Make informed ethical decisions
- Identify symptoms of a ruptured cerebral aneurysm
- Identify brain AVMs and associated brain bleeds in MRI

2. Design (Mapping the activity & instructional planning)

Each scenario day is mapped into an outline and a spreadsheet with all of the following information.

- Course Objectives
- Scenarios Objectives/Learning points-what will be practiced
- Design Elements-catastrophic events, cast of characters, images, scans, resources, checklists
- Assessment-decision points that address learning points (non-punitive, repetitive)
- Instructions-pre-learning needed, scenario resources, navigation, decision points, grading
- Day in the Scenario- objectives, goals, trigger event, mission, role, cover story
- Patient description
    - Patient story
    - Patient Chart -Demographics, neurologic exam, history present illness, surgical history, medications, allergies, past medical history, vitals, lab results, MRI screening form, prior imaging exams
    - Symptoms
    - Exam/s ordered
    - Protocol
    - Ultimate diagnosis
    - Prognosis
- Quick Response Practice
- Ethical Decisions
- Storyline script

Instructional Planning

Scenario Decision Points: The simulation has several decision point questions. The questions are multiple choice, multiple select, or drop and drag. Each answer (correct and incorrect) will provide intrinsic or instructional feedback. Supporting feedback will also be available on request by the student both before and after they make a decision about what to do. The decisions are in a branching format and will change the course of the storyline based on the student's responses.

Video presentations: Actual MRI scans are provided in a video format so students can scroll through the images just as they would on a real MRI scanner.

Resources: Students are provided with documents containing definitions, guidelines, recommendations, and requirements for MRI safety.

Rapid Response Questions: Students are provided with timed slides that are strategically placed in appropriate locations within some of the scenarios. These slides challenge the student to think and act quickly similar to actual events that occur in the clinical environment. The student must quickly assess the situation and respond appropriately within the given time frame. The student will receive a rapid response score in conclusion of the rapid response activity.

3. Formative Evaluation

Process

The process for the formative evaluation is done by content experts in radiology. Reviewers are all radiology professors who are at least somewhat familiar with the content area. All have a background with online instruction and a few have experience in online course development. They teach at varying levels and have differing areas of expertise. One reviewer has a 30-year background in radiology and biomedical engineering both as an instructor and in the field.

APPENDIX E

Instructional Design Outline-CT (example with script removed for brevity)

Instructional Design Outline
Kimberly Onstott

Principles of CT-Scenario-based Simulation

I. Course objectives:

- Understand and apply best standards in patient care.
- Describe appropriate CT radiation safety practices.
- Discuss dose reduction techniques.
- Identify and define CT procedures.
- Discuss image production including evaluation and archiving

II. Scenario Objectives

A. Scenario 1: Patient Care and Neurologic Anatomy and Imaging

- Apply communication skills with virtual patients and colleagues in CT
- Apply patient exam preparation skills with virtual patients in CT
- Apply radiation safety knowledge in the virtual CT suite (justification, optimization, limitation)
- Identify pathologies and anatomy of the brain on CT images and apply basic parameters for scanning a CT brain.

B. Scenario 2: Patient Care and Thoracic Anatomy and Imaging

- Apply communication skills with virtual patients and colleagues in CT
- Contrast media Injections-Apply patient exam preparation skills with virtual patients in CT
- Contrast media adverse Reactions-Identify contraindications and apply knowledge of adverse reactions with virtual patients in CT
- CT Angiography-Identify pathology and the anatomy of the thoracic vasculature on CT images and apply basic parameters for scanning a CTA thorax

C. Scenario 3: Patient Care and Abdominopelvic Anatomy and Imaging

- Communication, preparation, & Dosimetry-Apply communication skills with virtual patients and colleagues in CT
- Contrast media Injections-Apply patient exam preparation skills and identify contraindications for adverse reactions with virtual patients in CT
- CTPA pulmonary Angiography-Identify pulmonary embolism on CT images

D. Scenario 4: Patient Care, HIPAA, Esophageal Imaging

- Communication, preparation, & Dosimetry-Apply communication skills with virtual patients and colleagues in CT
- Identify HIPAA violations and medical identity theft
- Identify Perforated Esophagus

III. Scenario 1-Design Planning

A. Catastrophic Events

B. Cast of Characters

C. Operations- questions, decision points, and resources for Patient #1-Neuro patient

1. Questions and feedback
2. Decision points and feedback
3. Images
4. Scans
5. Resources-checklist, anatomy review websites, glossary

D. Patient description

1. Patient story
2. Patient Chart -Demographics, neurologic exam, history present illness, surgical history, medications, allergies, past medical history, vitals, lab results, MRI screening form, prior imaging exams
3. Symptoms
4. Exam/s ordered
5. Protocol
6. Ultimate diagnosis
7. Prognosis

IV. Scenario Slides

A. Title [Scene 1-Slide 1] RADS 4703 Scenario #1-Patient Care and Neuroimaging ©2018 Kimberly Onstott MSRS, RT(R)(CT)(MR)

B. Objectives [Slide 2]

1. Process knowledge goals:
   - Apply Communication Skills in CT
   - Apply Patient Preparation Skills in CT
   - Apply Dosimetry Knowledge in CT (Justification, Optimization, and Limitation)
   - Apply Basic Parameters for Common Neuroimaging CT Procedures
2. Content knowledge goals:
   - Review and use CT terminology
   - Review Basic CT Physics and Instrumentation
   - Review Quality control and post-processing in CT
   - Review Sectional Anatomy of Neuroanatomy

C. Instructions [Slides 3-6]

1. What you will Need
2. Navigation
3. Decision Points

4. Grading…

D. Preliminary discussion [Slides 7-9]:

1. Why is this important? Trigger event …
2. Mission and role…
3. Cover story…

E. Story Design-Script [Slide numbers vary as branching design includes additional slides for different choices the student makes]

1. Background Story
   a) *Introduction to hospital system*
   b) *Campus history*
   c) *Introduction to Radiology director*
   d) *Introduction to problems in CT*
2. Introduction to CT
   a) *Introduction to antagonist*
   b) *Set up storyline*
3. Address objectives
   a) *CT rooms, equipment, physics*
   b) *Checklists*
   c) *Ethical dilemma*
   d) *Rapid response*
   e) *Patient history*
   f) *Protocol*
   g) *Brain anatomy and pathology*
      (1) Intracranial bleeds-EDH, SDH, SAH
      (2) Intracerebral hemorrhage
   h) *Stroke*
      (1) Hemorrhagic
      (2) Ischemic
   i) *Stroke Protocol*
   j) *Patient introduction*
      (1) Communication dilemma
      (2) AIDET & SAMPLE introduction
   k) *Scan position and protocol-dose reduction*
   l) *Pathology identification*
   m) *Patient outcome*

F. Review what was learned

G. What to do next

[This continues through all 4 scenarios]

APPENDIX F

Instructional Design Spreadsheet (example)

	A	B	C	D	E
1	Main Objectives	Day 1	Learning points	Branching/Assessment	Resources
2		Patient 1			
3		Objectives	Reinforce looking at chart for history and priors, reinforce getting a good verbal history/assessment, CPR practice, and ethical decisions surrounding patients rights	Practice investigative techniques for implanted medical devices. Analyze images and imaging protocols for pathology involving the head. Demonstrate recognition of critical pathology. Recall standard imaging procedures of the head. Recall sectional anatomy of the head.	
4	Make informed and appropriate decisions about critical events in MRI	Quick Response Practice	CPR-Wife experiences chest pain and collapses while helping to give history. Seizure-Patient experiences seizure in the MR suite zone 4	CPR and Seizure Drag and drop assessment	BLS CPR Refresher Video
5		Ethical Decisions	Patient refusal		
6	Screen your patients for potential internal hazards, potential external hazards, and health issues that may cause harm to the patient while in the magnetic field or during the MRI exam	Exam/s ordered	MRI Brain w/wo contrast, CXR		Documents:
7	Make informed and appropriate ethical decisions about patient care in MRI	Ultimate diagnosis	Metastatic brain tumor with intracerebral hemorrhage.		ACR Guidance Document on MR Safe Practices: 2013
8	Educate uninformed technologists, staff, and healthcare workers about MRI safety	Prognosis	Poor		http://onlinelibrary.wiley.com/doi/10.1002/jmri.24011/pdf
9	Identify the abnormalities on the MRI exams	Type of patient	Outpatient male 60 years old Asian; does not live in the area. On a 3 month extended business trip. Has pacemaker (not in chart or history sheet). Hx of		MRI Safety 10 Years Later https://www.psqh.com/analysis/mri-safety-

APPENDIX G

Interview Questions

Participants will be asked:

Demographics

1. How old are you?
2. What is your radiology professional experience?
3. What is your program of study at MSU?
4. In how many simulation experiences (live and virtual) have you participated?
5. How many scenario-based (or story-like) simulations have you participated in?
6. Tell me about your simulation and scenario experiences as a radiology student.
7. What is your level of confidence with virtual technology?

Fidelity (Realism)

8. What characteristics of the scenario-based activity were meaningful to you? Why?
9. Tell me about how you felt about the atmosphere of the virtual space.
10. Comparing virtual scenario-based simulation and other online learning activities what specifically seemed to help you gain more skill and knowledge?

Self-Confidence

11. How does the simulation affect your confidence in clinical or laboratory decision-making situations?

12. Tell me about your experience in the ability to do things in a virtual scenario-based simulation compared to clinical or laboratory experience.
13. How did you feel when making critical decisions in the virtual experience?
14. What makes you feel more confident, virtual scenario-based simulation or clinical or laboratory experience?

Usefulness

15. How do you see virtual scenario-based simulations and online courses fitting together or not fitting together?
16. How do you see virtual scenario-based simulations fitting into your overall program of study?
17. Tell me about your level of engagement with the virtual scenario-based experience as compared to other online activities.
18. What benefits have you gained from your virtual simulation experience?
19. What recommendations do you have for similar activities in your online courses?

Open

20. Can you tell me anything new about virtual scenario-based simulations that we have not covered?

APPENDIX H

Survey Instruments

Simulation Design Scale (Student Version)

In order to measure if the best simulation design elements were implemented in your simulation, please complete the survey below as you perceive it. There are no right or wrong answers, only your perceived amount of agreement or disagreement. Please use the following code to answer the questions.

Use the following rating system when assessing the simulation design elements: 1 - Strongly Disagree with the statement 2 - Disagree with the statement 3 - Undecided - you neither agree or disagree with the statement 4 - Agree with the statement 5 - Strongly Agree with the statement NA - Not Applicable; the statement does not pertain to the simulation activity performed.							Rate each item based upon how important that item is **to you.** 1 - Not Important 2 - Somewhat Important 3 - Neutral 4 - Important 5 - Very Important				
Item	1	2	3	4	5	NA	1	2	3	4	5
Objectives and Information											
There was enough information provided at the beginning of the simulation to provide direction and encouragement.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
I clearly understood the purpose and objectives of the simulation.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
The simulation provided enough information in a clear matter for me to problem-solve the situation.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
There was enough information provided to me during the simulation.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
The cues were appropriate and geared to promote my understanding.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
Support	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
Support was easily available within the simulation.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
I felt supported by the available feedback within the simulation.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
The tips, feedback, and consequences	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5

helped me feel supported in the learning process.											
Problem Solving	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
Independent problem-solving was facilitated.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
I was encouraged to explore all possibilities of the simulation.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
The simulation was designed for my specific level of knowledge and skills.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
The simulation allowed me the opportunity to prioritize assessments and care.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
Feedback/Guided Reflection	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
Feedback provided was constructive.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
The simulation allowed me to analyze my own behavior and actions.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
Fidelity (Realism)	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
The scenario resembled a real-life situation.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5
Real life factors, situations, and variables were built into the simulation scenario.	□1	□2	□3	□4	□5	□NA	□1	□2	□3	□4	□5

Student Satisfaction and Self-Confidence in Learning

Instructions: This questionnaire is a series of statements about your personal attitudes about the instruction you receive during your simulation activity. Each item represents a statement about your attitude toward your satisfaction with learning and self-confidence in obtaining the instruction you need. There are no right or wrong answers. You will probably agree with some of the statements and disagree with others. Please indicate your own personal feelings about each statement below by marking the numbers that best describe your attitude or beliefs. Please be truthful and describe your attitude as it really is, not what you would like for it to be. This is anonymous with the results being compiled as a group, not individually.

Mark:

1 = STRONGLY DISAGREE with the statement

2 = DISAGREE with the statement

3 = UNDECIDED - you neither agree or disagree with the statement

4 = AGREE with the statement

5 = STRONGLY AGREE with the statement

Item	1SD	2D	3UN	4A	5SA	NA
Satisfaction with Current Learning						
The teaching methods used in this simulation were helpful and effective.	☐1	☐2	☐3	☐4	☐5	☐NA
The simulation provided me with a variety of learning materials and activities to promote my learning.	☐1	☐2	☐3	☐4	☐5	☐NA
I enjoyed how the simulation was taught.	☐1	☐2	☐3	☐4	☐5	☐NA
The teaching materials used in this simulation were motivating and helped me to learn.	☐1	☐2	☐3	☐4	☐5	☐NA
The way the simulation was taught was suitable to the way I learn.	☐1	☐2	☐3	☐4	☐5	☐NA
Self-confidence in Learning						
I am confident that I am mastering the content of the simulation activity that was presented to me in the simulation	☐1	☐2	☐3	☐4	☐5	☐NA
I am confident that this simulation covered the critical content necessary for the mastery of the MRI or CT curriculum.	☐1	☐2	☐3	☐4	☐5	☐NA
I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform the necessary tasks in a clinical setting.	☐1	☐2	☐3	☐4	☐5	☐NA
Helpful resources were included to teach the simulation.	☐1	☐2	☐3	☐4	☐5	☐NA
It is my responsibility as the student to learn what I need to know from this simulation activity.	☐1	☐2	☐3	☐4	☐5	☐NA
I know how to get help when I do not understand the concepts covered in the simulation.	☐1	☐2	☐3	☐4	☐5	☐NA
I know how to use simulation activities to learn the critical aspects of these skills.	☐1	☐2	☐3	☐4	☐5	☐NA
It is the instructor's responsibility to tell me what I need to learn about the simulation activity content during class time.	☐1	☐2	☐3	☐4	☐5	☐NA

APPENDIX I

Codebook

Nodes\\Design Characteristics

Descriptions of the design of the activity and the virtual space.

Name	Description
Curriculum Integration	The manner in which the simulation is presented within the course.
Perceived Usefulness	This describes how the student perceives this activity as useful or not useful.
Apply to practice	Usefulness of the activity in applying it to current or future practice.
Course Recommendations	Usefulness of the activity in the students' recommendations for similar activities in other courses.
Online Use	Usefulness of the activity in applying it to the online learning environment.
Retention	Usefulness of the activity in retaining the learned information.
Feedback /Support	Parent node to help identify all mentions of feedback and how they are experienced by the learner. These are either immediate, instructional, and Intrinsic-branching tips, in the form of a consequence, a coaching dialogue, or as a domain expert's stories about similar experiences.
Intrinsic	
Instructional	
Non-Punitive	
Reflection (worksheets)	Pre-planning, during, and post reflection
Repetition	
Supporting Feedback	
Fidelity_Realism_Relatable	Describes learner's experience relative to how real patient characteristics, technologist characteristics, environmental characteristics, and clinical practice is perceived.
Goals, Mission, Story, Role	Descriptions of the storyline in regards to the student's role within the story, the goals of the story, the mission, and the story itself. GBS Strategy of design.
Guidance & Instruction	Instructions and images to help the learner understand how the simulation works and continued guidance to assist the learner in completing the tasks in each scenario day.
Navigation	Describes how easily the learner is able to use the tools provided to progress through the simulation.
Scaffold	Providing full support at the beginning with simple tasks. Increasing complexity in tasks with diminishing tips to encourage independence and full autonomy in task exploration.

Objectives (Task deliverables) & Scenario Resources	Describes the learning objectives in each scenario day. Describes whether the instructions lay out all items necessary for the learner to be able to resolve or complete the scenario. Describes the available information within the simulation to be able to complete the objectives (EHR, Images, Videos, Text, External artifacts, etc.).
Problem Solving	Identifying and analyzing problems. Using resources to solve problems. Appraise outcome of solutions.
Recommendations	Mention of recommendations by the students for future design.
Self-Efficacy & Transfer	Belief in his or her capacity to execute behaviors necessary to complete the tasks either virtually or in transference to the clinical environment.
Assessment	autonomy, delay of assessment, non-punitive worksheet (concept map and reflections)

Nodes\\Confidence

Student confidence either in decision making or in the learning process

Name	Description
Confidence in decision making	This describes whether the student is confident in making critical decisions. High level suggests they are confident in transferring their knowledge to clinical practice. Moderate confidence suggests they are confident in the virtual world and it is undetermined if they are confident in transferring their knowledge to practice.
Confidence in learning	This describes whether the student is gaining confidence in learning through the use of the virtual simulation.

Nodes\\Satisfaction

Student satisfaction with the learning experience

Name	Description
Engagement Immersion	Level of engagement from low level to full immersion.
Fun_Humor_Comic Relief	Describes instances of fun, humor, or comic relief that suggest the design of the activity is not too cognitively demanding. Psychologically, humor is used by many healthcare professionals as a coping mechanism where one is confronted with urgency, tragedy, and emotional stress multiple times a day.
Gallows humor	Gallows humor is humor that treats the serious, frightening, or painful subject matter in a light or satirical way. It is used as a coping mechanism for health care workers.

Perceived Usefulness	This describes how the student perceives this activity as useful or not useful.
Apply to practice	Usefulness of the activity in applying it to current or future practice.
Course Recommendations	Usefulness of the activity in the students' recommendations for similar activities in other courses.
Online Use	Usefulness of the activity in applying it to the online learning environment.
Retention	Usefulness of the activity in retaining the learned information.
Safe	The activity allows the learner to feel safe in learning critical information without causing harm to patients. This may also describe the ability to make mistakes without consequence.
Time	time perception distortion alludes to gaming properties of flow and immersion

APPENDIX J

Virtual Scenario Objectives

CT Scenario Objectives

Scenario 1: Patient Care and Neurologic Anatomy and Imaging

- Apply communication skills with virtual patients and colleagues in CT
- Apply patient exam preparation skills with virtual patients in CT
- Apply radiation safety knowledge in the virtual CT suite (justification, optimization, limitation)
- Identify the pathologies and anatomy of the brain on CT images and apply basic parameters for scanning a CT brain.

Scenario 2: Patient Care and Thoracic Anatomy and Imaging

- Apply communication skills with virtual patients and colleagues in CT
- Contrast media Injections-Apply patient exam preparation skills with virtual patients in CT
- Contrast media adverse Reactions-Identify contraindications and apply knowledge of adverse reactions with virtual patients in CT
- CT Angiography-Identify pathology and the anatomy of the thoracic vasculature on CT images and apply basic parameters for scanning a CTA thorax

Scenario 3: Patient Care and Abdominopelvic Anatomy and Imaging

- Communication, preparation, & Dosimetry-Apply communication skills with virtual patients and colleagues in CT
- Contrast media Injections-Apply patient exam preparation skills and identify contraindications for adverse reactions with virtual patients in CT
- CTPA pulmonary Angiography-Identify pulmonary embolism on CT images

Scenario 4: Patient Care, HIPAA, Esophageal Imaging

- Communication, preparation, & Dosimetry-Apply communication skills with virtual patients and colleagues in CT
- Identify HIPAA violations and medical identity theft
- Identify Perforated Esophagus

MRI Scenario Objectives

Scenario 1: Patient Care, MRI Safety, and Brain Anatomy

- Apply communication skills with virtual patients in MRI
- Perform basic life support
- Recognize MRI safety zones and levels of personnel
- Make informed ethical decisions
- Research implanted medical devices
- Identify brain metastases
- Identify brain anatomy

Scenario 2: Patient Care, MRI Safety, Contrast Media, and MS Imaging

- Apply communication skills with virtual patients and colleagues in MRI
- Apply patient exam preparation skills with virtual patients in MRI
- Know MRI safety zones and levels of personnel
- Make informed ethical decisions
- Calculate and interpret Glomerular Filtration Rate (GFR)
- Identify contraindications for MRI contrast media-NSF
- Identify multiple sclerosis on MRI
- Identify specific MRI sequences for multiple sclerosis (MS)
- Identify external hazards

Scenario 3: Patient Care, MRI Safety, and Abdominopelvic Anatomy and Imaging

- Apply patient exam preparation skills with virtual patients in MRI
- Interpret SAR limits
- Identify thermogenic risks of RF power
- Reduce burn risks with protocol adjustments
- Make informed ethical decisions
- Identify symptoms of pancreatitis
- Identify abnormal pancreas pathology
- Know first aid for RF burns

Scenario 4: Patient Care, MRI Safety, and Cerebral Anatomy and Imaging

- Apply patient exam preparation skills with virtual patients in MRI
- Prevent external hazards
- Know first aid for projectiles
- Make informed ethical decisions
- Identify symptoms of a ruptured cerebral aneurysm
- Identify brain arteriovenous malformations (AVM) and associated brain bleeds in MRI

APPENDIX K

IRB Approval

Human Subjects
In Research
Committee

Institutional Review Board in
Compliance with 45 CFR 46

MSU Policy 2.37

MEMORANDUM

TO: Kimberly Onstott; Lynette Watts; Mandy Sedden

RE: Impact of Virtual Scenario-based Branching Simulations Among Radiology Program Students

DATE: February 20, 2019

Your proposal for research utilizing human subjects has been reviewed and approved by the above named committee.

The number assigned this project is 19021201.

Please include this file number in any presentation or publication arising from this research. You may be required to place a copy of this letter within the thesis or other class, department, or college documentation. This approval is valid excepting that none of the previous conditions change. If conditions to the application change, you may request an extension by submitting a letter requesting such to the HSRC committee chair.

Respectfully,

Stacia C. Miller

Stacia C. Miller, Ph.D.
Chair, Human Subjects in Research Committee (IRB)