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# What is the Relationship Between Success on the Limited X-Ray Machine Operator Exam and the First-Attempt Pass Rate on the National Registry Exam Among Radiologic Technology Students in Minnesota?

Britni Hardy
*Winona State University*

# What is the relationship between success on the Limited X-Ray Machine Operator exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota?

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WHAT IS THE RELATIONSHIP BETWEEN SUCCESS ON THE LIMITED X-RAY MACHINE OPERATOR EXAM AND THE FIRST-ATTEMPT PASS RATE ON THE NATIONAL REGISTRY EXAM AMONG RADIOLOGIC TECHNOLOGY STUDENTS IN MINNESOTA?

Committee:

Steven Baule, PhD, Ed.D., Committee chair

Rhea Walker, PhD, Committee member

Aurea Osgood, PhD, Committee member

Steven Baule, ~~Chair~~

Rhea Walker

Aurea Osgood

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## Abstract

This quantitative correlational study examined the relationship between success on the Limited X-Ray Machine Operator (LXMO) exam and first-attempt pass rates on the national registry exam among radiologic technology students in Minnesota. The radiologic technology field faces significant challenges, including a 14.9% national attrition rate, workforce shortages, and limited availability of clinical sites. This research explored whether LXMO certification could serve as an innovative approach to address these interrelated issues. Data were collected from the Minnesota Department of Health and the American Registry of Radiologic Technologists, spanning 2000-2024, and identified n=24 students who had completed both exams. Results revealed that LXMO-certified students had a 70.8% first-time pass rate on the national registry exam, which is lower than the national average (85.2%) and the Minnesota average (83%), failing to support the hypothesis that LXMO certification would improve registry exam performance. The study was analyzed within the framework of Cognitive Load Theory, suggesting that LXMO exam preparation may create mental frameworks that are too narrow for the comprehensive registry exam. Despite these findings, the research highlights the potential practical benefits of LXMO certification, including increased clinical independence, reduced supervision requirements, and mitigation of workforce shortages. The small sample size (24 participants) and inability to account for factors such as timing between exams and student characteristics limit the generalizability of findings. Future research should expand to larger sample sizes across multiple states, employ longitudinal designs to examine optimal timing between exams, and incorporate mixed methods to better understand students' experiences with both certifications.


*Keywords*: radiologic technology, LXMO certification, national registry exam

## Contents

## Dedication

To my husband and mother, whose unwavering encouragement gave me strength, and to my children, whose patience and understanding made this journey possible. I am forever grateful to my students, whose thirst for knowledge and drive for growth have inspired me to pursue excellence in our shared passion for this field. Last, but certainly not least, to my dear friends, who provided emotional support, listened to my challenges, and celebrated each milestone—your friendship has been my sanctuary throughout this academic pursuit.

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## Chapter 1: Introduction

Medical imaging was discovered on November 8, 1895, by Wilhelm Conrad Röntgen (Tubiana, 1996). His discovery of X-radiation led to the development of ten different modalities used in healthcare today, all of which fall under the general terminology of "radiology" (Tubiana, 1996). The most common are diagnostic radiology, interventional radiology, and radiation oncology (Tubiana, 1996). In the United States, 600 – 700 million exams are performed annually in radiology (Fornell, 2022).

Medical imaging technology, including radiologic and computed tomography, is a field with over 220,000 employees nationwide (U.S. Bureau of Labor Statistics, 2023). This makes it the third largest group of employees in hospitals nationwide, trailing only physicians and nursing services (American Registry of Radiologic Technologists, 2024). However, this field is highly competitive, with radiologic technology educational programs having to turn away an estimated 10,000 qualified students annually (ASRT, 2022). One of the key reasons for this is the scarcity of clinical site allocations (ASRT, 2023), a crucial component in developing competent radiologic technologists.

This study investigates the relationship between success on the Limited X-Ray Machine Operator (LXMO) exam and subsequent performance, specifically the first-attempt pass rate, on the national registry exam among radiologic technology students in Minnesota. By exploring this relationship, it seeks to evaluate the potential of LXMO certification as an innovative approach to address current challenges in radiologic technology education, including workforce shortages, high attrition rates, and limited clinical site availability (ASRT, 2023). Adding the LXMO certification to students in radiologic technology programs will not only allow them autonomy

and independence but also significantly boost their confidence as they perform exams at which they are deemed competent.

Beyond certification pathways, the profession has been pursuing broader strategies for advancement. Educators have encouraged students to obtain their bachelor's and master's degrees upon completing their radiography program to advance the field's technical designation to professional status, following the same path as the registered nurse national designation. This push for higher education credentials represents one approach to enhancing professional recognition. At the same time, innovative certification pathways, such as Limited X-ray Machine Operator (LXMO), may offer complementary benefits for educational outcomes and workforce development.

**Background of the Problem**

The radiologic technology field faces complex challenges, including a national workforce shortage and high attrition rates among programs. Over the past five years, from 2020 to 2024, attrition rates have fluctuated due to the pandemic's effects; however, this research does not account for these pandemic-related issues. Year after year, fluctuations in the attrition rate decrease, but the overall number has increased over the last five years (American Society of Radiologic Technology, 2024). As a result of the workforce shortage, clinical site availability has been reduced to ensure compliance with the Joint Review Committee on Education in Radiologic Technology (Joint Review Committee on Education in Radiologic Technology). A reduced number of radiologic technologists available for students to work within the clinical setting equates to fewer students placed at those clinical sites, thereby maintaining compliance with the JRCERT policy. According to the American Registry of Radiologic Technology's survey of student access to clinical sites, among the 399 survey respondents who lost clinical spots due to

worker shortages, 342 stated that their program would accept more students if additional clinical sites were available (ARRT, 2024). JRCERT nationally accredited programs must comply with restrictions implemented through accreditation; failure to do so risks losing accreditation status. Recent data confirms that these challenges continue to worsen. According to the 2024 Consensus Committee report (ASRT, 2024), over 67% of imaging facilities report staff shortages that affect clinical education, and approximately 53% of programs have lost clinical spots due to understaffing, competition between programs, or an inability to provide required modality training.

These interrelated issues necessitate creative solutions, such as the potential integration of LXMO certification into radiography programs to increase students' abilities to complete exams confidently, work more independently with patients to meet their individual needs, and, lastly, gain experience in challenging a standardized exam developed by the same organization that created the national registry exam to become a registered radiologic technologist. The value of adding the LXMO certification exam as a requirement for all students has the potential to address workforce challenges by giving students the ability to do some exams independently. It may alleviate high attrition rates, as students in the clinical setting can control aspects of their learning through repetition and independence, rather than relying solely on direct interactions with radiologic technologists to meet many of their learning needs.

The American Society of Radiologic Technologists (ASRT) reports fluctuating national attrition rates in radiography programs: 15.6% in 2020, decreasing to 12.7% in 2021 and 11.9% in 2022, before rising again to 15% in 2023, and 14.9% in 2024. Simultaneously, 44.5% of radiography programs reported operating below total capacity (ASRT, 2024).

A significant workforce shortage of practicing, registered radiologic technologists exists across all branches of radiology, most severely in diagnostic radiology (ASRT, 2024). General radiology and computed tomography (CT) account for approximately 35.8% of all radiology department position shortages, with large healthcare organizations facing approximately 19.8 Full-Time Equivalent (FTE) position vacancies (ASRT, 2023). This shortage directly impacts educational programs by limiting student acceptance, as approximately 3,900 program directors have had to reduce student intake due to staffing shortages (ARRT, 2024). In Minnesota, 50% of educators have lost clinical site spots due to understaffing, with an average of 2 clinical spots lost per program (ARRT, 2024). Approximately 53% of programs report reductions in clinical site availability due to COVID era staffing impacts, insufficient education coverage for accreditation-required modalities, and competition between multiple educational programs for the same clinical sites (ARRT, 2024).

As a result, many programs have limited annual student acceptance to approximately 86% of their regular capacity (ARRT, 2024), resulting in approximately 13,511 qualified students being denied entry in 2023. This situation has worsened significantly in 2024, with an estimated 22,780 qualified students being turned away from radiography programs (ASRT, 2024). This dramatic increase further exacerbates the national shortage of radiologic technologists, creating a cyclical problem where workforce shortages lead to reduced educational capacity, which worsens the shortage.

Given these interconnected challenges of workforce shortages, limited clinical site availability, and high program attrition rates, educators and industry leaders are exploring creative solutions. One potential approach is through the ARRT's Limited X-ray Machine

Operator (LXMO) exam (ARRT, 2023). Adding student LXMO certification could alleviate current stresses for staff radiologic technologists while helping programs ensure students receive quality clinical experiences despite the challenging environment. This certification represents a promising approach to addressing the problematic cycle of technologist shortages and educational constraints in the radiologic technology field.

The ARRT has formal radiography education requirements that must be met before challenging the national registry exam. The requirements entail completing an ARRT-approved educational program in radiography (ARRT, 2024). Accreditation through the JRCERT would be one of the most commonly accepted routes to ensure that students in programs have access to national registry exams (ARRT, 2024). Other accreditation-acceptable formats include those through regional institutional accrediting agencies, such as the Higher Learning Commission (ARRT, 2024). For programs within institutions that may already hold regional accreditation, programmatic recognition may be obtained from the Commission on Accreditation of Allied Health Education Programs (CAAHEP) or the Accrediting Bureau of Health Education Schools (ABHES) (ARRT, 2024).

The LXMO qualifies individuals to perform essential radiography exams but limits their scope and ability in other modalities of radiology departments (ARRT, 2023). Radiologic technology students can take the national registry exam at the end of an accredited radiologic technology program to become certified, which allows for a broader scope within the field of radiography (ARRT, 2024).

A LXMO-certified student could perform routine imaging exams independently under indirect supervision policies applied and required by the Joint Review Committee on Education of Radiologic Technologists (JRCERT) (JRCERT, 2021). The JRCERT is the only national

accreditation agency specifically for radiologic technology programs. While remaining compliant with accreditation, staff radiologic technologists at clinical sites can dedicate more time to teaching more novice students through constant education and reinforcement.

According to a 2023 study by Nieuwenhuis et al., an individual's prior exposure to information and their current physiological state are both essential aspects of their learning process. Researchers suggest that understanding how these two factors influence a person's effort provides a pathway for examining various influences on effort-based decision-making during relevant tasks (Nieuwenhuis et al., 2023). Currently, as a policy of the JRCERT, students are required to perform in the clinical setting under direct supervision until they have proven competence through a set of tasks implemented in each educational program (JRCERT, 2021). Once the student demonstrates competence in the clinical setting through adequate task-based performance, indirect supervision is an acceptable policy, as established by the JRCERT (2021), in the general radiology modality.

Implementing an LXMO exam pathway may help build confidence in students and their clinical abilities. Once the student has demonstrated competence as determined by the educational program, another layer of competence can be achieved through a standardized exam created by the ARRT (2023). Combining the JRCERT supervision policies with implementing the LXMO certification may allow students to achieve independence within the clinical setting, outside the scope of the JRCERT supervision policy. Understanding this potential integrated perspective enhances our understanding of how prior experience and knowledge may build confidence and shape students' effort-related choices and behaviors in academic settings. Once students are LXMO certified, hospital and clinic staff will be more available to teach novice students who still need to obtain LXMO certification. Novice students require direct supervision

and an in-depth learning environment, as they are less experienced than their senior, LXMO-certified students.

LXMO certification will benefit students in many ways. First, it may provide radiologic technology students with the experience of taking a state-level exam outside the classroom in a pre-approved testing center. Second, the testing environment's natural pressure will prepare students to challenge the national registry exam in a familiar environment. Third, the LXMO exam has the potential to build confidence in students that they are deemed proficient in a limited set of general radiography imaging procedures by an external agency, rather than by program faculty or staff radiologic technologists. This process will limit bias by any faculty or staff radiologic technologist. Lastly, the certification could enable students to work under indirect supervision and independently with patients during clinical rotations, thereby reducing the workload of the radiology department's technologists (JRCERT, 2021). In turn, all parties involved in educating students, whether in a didactic or clinical setting, will have confidence in their students' abilities to succeed in various aspects of radiography.

Adding the LXMO exam within radiologic technology programs may efficiently use limited clinical site resources, address some aspects of the workforce shortage by allowing students to contribute meaningfully during their clinical rotations, and potentially improve student outcomes and reduce attrition rates.

**Problem Statement**

The central problems in radiologic technology, including workforce shortages, high attrition rates, and limited clinical site availability, highlight a need for creative solutions to train and retain qualified radiologic technologists (ASRT, 2023). A subsequent challenge for program faculty is to decrease the attrition rate of radiologic technology students while building

proficiency and adequate skills in a challenging clinical environment through the students' clinical rotation experiences. The staff technologist shortage makes it increasingly difficult for programs to ensure students receive a quality clinical experience and build independent clinical skills (ASRT, 2023). The 2024 Consensus Committee on the Future of Medical Imaging and Radiation Therapy (ASRT, 2024) emphasizes that these workforce challenges require "innovative solutions from the profession as a whole" to address staffing shortages while maintaining high-quality patient care.

Integrating LXMO certification into radiologic technology programs represents a potential approach to addressing the persistent workforce shortage and other challenges educational programs face in this field (ASRT, 2024). This study aims to investigate whether success on the LXMO exam correlates with improved performance, as indicated by the first-attempt pass rate of the national registry exam, potentially offering insights into an innovative strategy for enhancing radiologic technology education and addressing industry-wide staffing issues.

**Purpose of the Study**

A correlational study will examine relationships between student success on the Limited X-ray Machine Operator (LXMO) exam and subsequent first-attempt performance on the national registry exam from Minnesota programs, using data from the Minnesota Department of Health (MDH) and ARRT. This research may inform strategies to utilize clinical resources more effectively, improve student outcomes, and help mitigate current shortages of radiologic technologists, highlighting the importance of innovation in radiologic technology education.

**Population and Sample**

Research will examine the relationships between student performance on the LXMO and national registry exams. Specifically, looking at students enrolled in Minnesota programs. In Minnesota, thirteen JRCERT-accredited programs and one Higher Learning Commission-accredited radiologic technology program enroll up to 575 students annually. Data is supplied by the Minnesota Department of Health (MDH), which houses the registration application, to verify applicant validity through a background check before granting approval to register for the LXMO exam, created by the ARRT (MDH, 2024). The ARRT organization maintains a national registry of student exam results, including passing and failing grades, as well as a nationwide database of registered radiologic technologists. This study hypothesizes that student performance on the LXMO certification positively correlates with first-attempt pass rates on the national registry exam.

**Significance of the Study**

Research examines the correlative relationships between prior success on an LXMO exam and subsequent performance among students in nationally accredited programs, with a focus on the first-attempt pass rate of the national registry exam. Based on the potential advantages of LXMO certification for radiologic technology students during challenging healthcare shortages, this process may help address industry-wide staffing shortages of radiologic technologists. The creative use of available radiologic technology resources can improve education, training, and fieldwork by implementing additional methods of demonstrating competence from an objective and unbiased source.

The MDH provides public, secondary data containing LXMO-certified individual names. The list of names from the MDH is sent to the ARRT. Data is compared to the MDH list with the

ARRT database, and an email with numerical data only will be sent to the researcher. The data generated from the ARRT will only include the total number of applicants who are both LXMO-certified and ARRT-certified, the number of those individuals who passed the national registry on their first attempt, and those who did not.

**Nature of the Study**

This study uses a quantitative research design. As Creswell and Creswell (2023) define it, quantitative research tests objective theories by analyzing relationships among variables or comparing groups using numerical data and statistical procedures to highlight causal connections. This study utilizes correlational research from secondary data sources, including the Minnesota Department of Health (MDH) and the American Registry of Radiologic Technologists (ARRT). Creswell and Creswell (2023) further define correlational research as the study of a relationship between two variables. Both dependent and independent variables will be assessed in this research.

**Research Questions**

Hypothesis question:

**RQ1:** What is the relationship between passing the Limited X-Ray Machine Operator (LXMO) exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota?

**H1:** There is a significant positive correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota.

**H1N:** There is no significant correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota.

## Theoretical Framework

Research is examined within the cognitive load theory (CLT). According to Sweller (1988), working memory in CLT has a limited capacity to hold information, and instructional methods should avoid overloading it to maximize learning. Using this theoretical framework will support my hypothesis that prior exam experience, as demonstrated by taking the LXMO exam, facilitates the transfer of information from working memory to long-term memory for retrieval rather than memorization. This process creates additional space in working memory, enabling the acquisition of a broader scope of information necessary to become a radiologic technologist. The CLT supports theories such as the predictive validity concept developed by Meehl and Challman in 1954, which is used to predict and perceive your surroundings (Van Elk, 2021). The predictive validity concept predicts that the LXMO exam success rate will correlate to the national registry exam's subsequent first-attempt pass rate.

Another theory CLT supports is the transfer of learning theory, which originated in 1901 with Thorndike and Woodworth. This theory states that knowledge and skills are transferable if past learning is similar to new situations (Haskell, 2004). This framework predicts a positive correlation between the LXMO and national registry exams.

## Definition of Terms

All the following terms were used in this study. For this research study, definitions of these terms are:

***American Registry of Radiologic Technologists (ARRT).*** This organization is a primary authority in credentialing for medical imaging, interventional procedures, and radiation therapy professionals; ARRT's certification and registration process is comprehensive. It manages and incorporates education, ethics, and examination requirements, ensuring a high standard of competence in radiography (ARRT, 2024).

***American Society of Radiologic Technologists (ASRT).*** It is an educational leader for all medical imaging and radiation therapy professions dedicated to enhancing patient care quality and safety. As a premier professional association, ASRT focuses on education, advocacy, research, and innovation, ensuring high standards in the field (ASRT, 2024).

***Clinical Preceptor.*** Refers to an individual skilled in supervision, instruction, and evaluation, with a documented two-year clinical experience in the professional discipline. Individuals must maintain current certification and registration with the ARRT equivalent organization in radiography (JRCERT, 2021).

***Joint Review Committee on Education in Radiologic Technology (JRCERT).*** Maintains professional standards that support academic integrity and quality. This association accredits educational programs in radiography, radiation therapy, magnetic resonance imaging, and medical dosimetry to promote exemplary healthcare (JRCERT, 2024).

***Limited X-ray Machine Operator Licensing Exam.*** An exam designed to certify individuals operating radiographic equipment for specific anatomic regions. It ensures that these individuals demonstrate comparable knowledge and cognitive skills to those of general radiologic technologists, thereby maintaining consistent standards across all areas of radiography practice (ARRT, 2023).

***National Registry Exam*, also known as ARRT certification and registration,** formally acknowledges individuals who meet professional standards in medical imaging, interventional procedures, or radiation therapy, qualifying them for specific roles, such as radiologic technologists or radiographers. This process ensures that certified individuals possess requisite qualifications and competencies for their designated fields within healthcare (ARRT, 2022).

***Pass Rate.*** Refers to the percentage of candidates who successfully pass a particular examination or assessment. It is often measured and reported alongside other metrics, such as mean scaled section scores, mean total scaled scores, and historical trends, to comprehensively understand candidates' performance over time (ARRT, 2021).

***Prior Success*** refers to the feedback or results received from previous task performance, which can influence an individual's subsequent performance and rate of mastery of new tasks. Its effects interact with a person's initial achievement orientation, potentially leading to positive or negative transfer effects, particularly when facing complex subsequent tasks (Latta, 1978).

***Radiographer/Staff Radiologic Technologist/Clinical Staff.*** Refers to individuals who acquire and maintain active radiography certification and registration through the American Registry of Radiologic Technologists (ARRT) or a comparable credentialing body (JRCERT, 2021).

***Relationship.*** It is described as a quantifiable connection or association among variables, particularly categorical data, that can be linear or nonlinear. It is typically represented through mathematical formulas, incorporating probabilistic views, and often expresses degrees of truth between connected variables (Arotaritei et al., 2020).

**Limitations/Delimitations/Assumptions**

A potential limitation to adding a LXMO exam to program requirements is access to the exam. Currently, only 34 states use the ARRT LXMO exam to certify people to administer radiation (ASRT, 2024). Implementing this exam into radiologic technology programs would not be equitable from an accreditation standpoint and cannot be mandatory by any external agency. Second, the financial burdens of registering for the exam and traveling to a testing center may pose a barrier to students. In Minnesota, the fees paid to the MDH and the ARRT are $25 and $150, respectively. However, there are potential solutions to these issues. It would be most beneficial if programs could embed exam costs into the program, arrange transportation for students to the testing center, and eliminate these barriers.

Additional research limitations may include the study's cross-sectional nature, as the data will only be examined once. This may limit the ability to establish causality or observe changes over time. Another potential study limitation may be self-selection bias, where students may choose to take the LXMO exam, indicating different characteristics or motivations than those who do not, which could potentially skew the results. Lastly, although practical, reliance on only secondary data from MDH and ARRT may limit the types of analyses possible and the specific variables available for study.

Another limitation of this study is the relatively small number of students who have taken both the LXMO and national registry exams in Minnesota. Preliminary data indicate that only 24 individuals completed both exams over the 25 years (2000-2024). While this represents the complete population of interest rather than a sample, this limited number may constrain the statistical power and generalizability of findings. This constraint reflects the current state of

LXMO certification adoption and highlights the exploratory nature of this initial research, which examines the relationship between these exams.

Research delimitations include the specificity of a correlation between the LXMO exam and the national registry exam's first-time pass rate. Secondary data collected from MDH and ARRT will quantify statistical data and demonstrate a potential correlation. A geographical focus on only programs in Minnesota will also add to study delimitations. The research will employ a quantitative approach; however, qualitative research may limit consideration to the collection methods and reliance on secondary data.

**Summary**

In conclusion, ongoing challenges within radiologic technology, including workforce shortages, increased attrition rates, and limited availability of clinical sites, underscore the need for inventive solutions. The possible integration of LXMO certification into radiography programs represents a potential approach to addressing these issues. Allowing students to gain certification through the LXMO exam and meeting all individual program requirements to prove competence will enable them to perform exams under indirect supervision, within the bounds of the JRCERT supervision policy. LXMO certification could alleviate pressure on clinical sites and technologists, enhance educational experiences, and reduce attrition rates.

This proposed study aims to investigate whether success on an LXMO exam is correlated with improved performance, as indicated by the first-time pass rate of the national registry exam. This would provide valuable insights into the value of a certification pathway. Research may inform strategies to utilize clinical resources more effectively, improve student outcomes, and mitigate current shortages of radiologic technologists, reinforcing the essential role of continued innovation in medical imaging.

Chapter II analyzes and evaluates current literature on this subject. Chapter III discusses the research methodology and processes applicable to this study, including participant selection, instruments used, data collection, data analysis, and ethical considerations. Chapter IV evaluates and presents data described in Chapter III. Lastly, Chapter V discusses the study's implications and recommendations for further research.

# Chapter II: Review of the Literature

## Introduction

This study addressed the challenge of improving the national registry exam pass rate for radiologic technology students by proposing the use of the LXMO exam. It could allow radiologic technology students to work under indirect supervision, as established by JRCERT policies, thereby enhancing their learning experience and future career.

The LXMO certification of radiologic technology students enabled them to work more independently in clinical rotations. Compared to the broader scope of the registered radiologic technologist, the predictive success of an exam of limited scope will bring significant benefits to the education and employment of radiologic technology students. This research is relevant and valued by the field.

While researchers have investigated factors that predict programmatic success in radiologic technology, the LXMO exam is overlooked as a variable in these studies. Factors related to the program, the student, and the coursework have been thoroughly studied. However, further research was needed on the LXMO as a formative assessment that might predict success on the national registry exam. This underscored the urgent and viable need for further research in this area, highlighting the potential of the LXMO exam as a predictor of success and the existing gaps in research.

Despite the potential of the LXMO exam as a predictor of success, more research studies are needed. This lack is attributed to the fact that only 34 states currently administer the LXMO exam for certification, which limits its use as a predictor of success on a national scale. This context was important for understanding the research landscape in radiologic technology

education, as it highlighted the pressing need for more comprehensive research on the LXMO exam.

This chapter will highlight the literature search strategy used. Due to the limited research directly referencing the LXMO exam, the study will be examined within the context of cognitive load theory (CLT). According to Sweller (1988), working memory in CLT has a limited capacity to hold information, and instructional methods should avoid overloading it to maximize learning. Using this theoretical framework will support the hypothesis that having prior exam experience, as evidenced by taking the LXMO exam, enables the transfer of information from working memory to long-term memory for retrieval rather than memorization. This process creates additional space in working memory, accommodating the acquisition of a broader scope of information necessary to become a radiologic technologist.

CLT supported theories, such as predictive validity, which is used to predict and perceive the world (Van Elk, 2021). The predictive validity concept of CLT predicted that the validity of the LXMO exam success rate will correlate with passing the national registry exam. Predictive validity indicated a positive correlation between the LXMO and national registry exams.

Established research directly supported the research hypothesis, which will help us better understand the potential value of the LXMO exam for educational programs, students, and healthcare facilities. The reviewed literature within the CLT theoretical framework will add depth and understanding of the possible impact of the LXMO exam, with the potential to either support or refute the hypothesis or the null hypothesis.

**Search Terms and Process**

The researcher searched Winona State University and Minnesota State College and University System databases. The following databases were searched for sources: ERIC,

CINAHL, Mental Measurements, ProQuest, Allied Health and Nursing, Ovid, JSTOR, ScienceDirect, PsycINFO, and PubMed. The databases examined were identified as indexing educational and health sciences literature, with a focus on radiologic technology literature. The original search terms used were: radiologic technology education, registry exam performance, limited-scope machine operator licensing, predictors of success in radiologic technology, certification exam correlation, correlation between preliminary exams and national registry performance in radiologic technology, predictors of success on radiologic technology certification exam, factors influencing pass rates on radiologic technology certification exams, and predictive validity of licensing exams in healthcare. The literature search was initially limited to 2019-2024, but was expanded. Exceptions were made, and additional extensions were added to the search dates of all years, as research related to this topic is limited.

Once applicable articles were retrieved, references were reviewed, and lists from those studies were compiled for all other relevant articles. Relevant articles were searched for in Google Scholar to identify other works that cited them. Those articles were reviewed for relevance and included if pertinent. One dissertation with a similar topic was reviewed during the literature review process. The reference lists from this dissertation were reviewed, and no relevant articles were referenced within this literature review.

Given the absence of recent research on factors predicting success on the LXMO exam before the national registry exam, a comprehensive approach was taken. This approach broadened the scope of the literature review-related exams to include licensed practical nurses (LPNs), registered nurses (RNs), medical laboratory technologists, optometrists, occupational therapists, pharmacists, and physical therapists. This expanded search was crucial to ensure a thorough understanding of the topic.

Most related literature on the predictive validity concept embedded within CLT has been completed in studies in allied healthcare. Still, it has also been done in nursing education and Optometric Schooling. These studies have focused on grade point average (GPA) and a second dependent variable that demonstrated predictive validity for graduates passing the National Council Licensure Examination (NCLEX).

**Historical Content**

Radiologic technologists have always maintained a pivotal role in any healthcare system. Their ability to image patients across multiple modalities using ionizing radiation within their scope of practice was a testament to their importance. Their credentials as R.T.(R), which stands for Radiologic Technologist (Radiography), signify their expertise in this field. They have also been cross-trained in various areas within healthcare facilities, under the scope of radiology, further highlighting their versatility and importance.

Around 1910, formal education in radiologic technology began with physicians training for an additional year after medical school to learn how to utilize radiation during patient imaging procedures (ASRT, 2023). After physicians were educated and employed medical radiation procedures, many began purchasing X-ray equipment for their medical offices (ASRT, 2023). Shortly after that, physicians began specializing in radiation practice, and the official title of radiologist was established (ASRT, 2023).

Once radiologists became experienced in the use of radiation, they began to train secretaries and other support personnel to operate the equipment. However, this training was often hindered by a lack of understanding or education about the principles of radiation and its manipulation among these individuals (ASRT, 2023). In October 1920, the American Association of Radiological Technicians was started (ASRT, 2023). This association established

a repository for individuals administering radiation to patients, allowing them to share ideas and information on obtaining adequate images for radiologists (ASRT, 2023). In the early 1950s, formal education standards were established, and formalized educational programs were introduced (ASRT, 2023). Their scope of practice was less than that of a radiologist. However, academic programs were created to teach patient positioning principles and the physics of radiation, allowing an understanding of the technique factors necessary for diagnostic images while ensuring safe patient exposures (ASRT, 2023). Formalizing educational programs was necessary to transform on-the-job training into a lifelong career.

According to the National League of Nursing, "Clinical education prepares students for their professional careers with real practice and guides their learning and research in contexts and their socialization in their professional roles to provide appropriate and effective patient care." (Hakim, 2023). Clinical education has been essential for all healthcare careers, as immersion in the field environment is necessary to develop competent and confident workers (Burns, 2013).

The College Entrance Examination Board, now known as the College Board, introduced the first widespread standardized tests in 1901 (Schudson, 1972). Distinct from classroom-based knowledge assessments, standardized tests are conducted under controlled conditions (Optometric Education, 2021). Optometric Education (2021) states that this approach compares student performance while theoretically controlling for external influences. Proponents of standardized testing often cite two main arguments: first, that the standardized nature of these tests removes potential bias, and second, that these examinations can provide an accurate measure of students' intellectual capabilities (Optometric Education, 2021).

### *Clinical Component*

Clinical rotations for radiologic technology students have been part of formal education programs since the early 1950s (ASRT, 2023). The clinical component of each radiologic technology program made up between half and two-thirds of the total time students spent in the program. (Burns, 2013). In a study conducted by Burns (2013), students, clinical preceptors, and staff radiologic technologists were surveyed about the importance of the clinical component in the educational process. All three groups agreed that the clinical component of education is the most essential aspect of learning about a radiology department's daily operations and functioning (Burns, 2013). Results indicate the importance of enhancing experiential aspects of clinical education, particularly in teaching, learning, and competence development (Burns, 2013).

The central role that clinical education plays in the education of radiologic technology students is evident; however, objectively assessing student knowledge, performance, and progression in the clinical setting by both program clinical preceptors and staff radiologic technologists can be inconsistent in evaluation. According to Frias (2002), his research demonstrated inconsistencies in applying the evaluation process predetermined by the educational program among evaluators, including program faculty, staff radiologic technologists, and clinical preceptors. Students in the program were not evaluated consistently across all areas scored during the evaluation process. This research demonstrates that bias is possible in any person-based evaluation process.

Another research study by Wyatt (2015) highlights the disconnect between student clinical evaluation performance and objectivity, as well as the need for accurate and unbiased assessment by clinical preceptors and staff radiologic technologists. The research emphasized the

need for an impartial evaluation of student performance and highlighted the gaps in research available in radiologic technology education.

The limited research available, both historical and current, in radiologic technology, as well as the need for an unbiased process to evaluate student performance, further underscores the necessity for an evaluation process that removes the human element and creates an impartial environment to promote equity among students and their successes or failures in the study of radiologic technology.

***Didactic to Clinical***

Research conducted by Drotar (2016) demonstrated the impact of a student's ability to transfer knowledge and competently perform entry-level clinical tasks, applying critical thinking skills acquired in the didactic setting. Transferring knowledge from a didactic to a clinical setting is imperative when developing foundational concepts and using them in practical situations. The didactic component of educational programs fundamentally supports the clinical element, allowing students to refine their abilities in the patient-care setting. A lack of foundation in a set of processes will prevent practitioners from adapting to situational differences throughout their education and career (Drotar, 2016).

In another research study conducted by Orders (2011), it was demonstrated that students' reflections on knowledge gained in the didactic setting were directly transferred into clinical decision-making processes. It was determined that the knowledge obtained through classroom and laboratory settings and didactic learning directly attributed to student performance and decision-making abilities during clinical rotations (Orders, 2011). Further interactions with patients and staff radiologic technologists in the clinical setting help to establish and develop logical reasoning and implementation of prior knowledge gained in the didactic setting.

The two studies have demonstrated that a student's knowledge acquired in a didactic setting directly transfers to clinical settings and influences their clinical decision-making processes. Experiences in clinical settings foster and build the development of reflective practice and complex problem-solving in students.

### *Predictors of Success*

Overall, there is minimal research on the predictors of success in radiologic technology programs. Sensitivity, specificity, and accuracy are all characteristics used to create certification exams that verify a test taker's competence in a specific area of study (Schmuck & Cook, 2018). The ARRT creates both the national registry exam and the LXMO exam, but only administers the national registry exam. MDH houses and administers the LXMO exam in Minnesota. The ARRT is a nationally recognized agency that ensures exam security by implementing strict security regulations that prohibit cheating on these exams (ARRT, 2024). Both examinations are protected under federal copyright legislation. Additionally, since the ARRT's headquarters are located in Minnesota, these exams are subject to the Minnesota Exam Subversion Law. This state law prohibits any actions that compromise or attempt to undermine the integrity of an examination (ARRT, 2024).

Predictors of success in established research have been studied, including GPA, prerequisite courses required and their success, GPA in select prerequisite courses, and Test of Essential Academic Skills (TEAS) composite scores. Each of the previously mentioned predictors of success evaluates a student's potential success before they start any radiologic technology program. Research in radiologic technology directly related to national registry exam success, based on in-program assessment, is limited.

A study conducted by Krupat et al. (2017) found that low academic performance in the first year of medical school is a significant predictor of poor performance in subsequent years of medical school. It would be assumed that a radiologic technology program would hold the same reasoning as a medical school education. It is similar in program structure and design, but differs in the breadth and scope of its content. Suppose a student performs poorly in their first year of a radiologic technology program. In that case, the unretained information from the didactic and clinical instruction will only be perpetuated in the program's second year. That student will remain a low-achieving student in the succeeding year.

In another research study, Schmuck & Cook (2018) investigated the predictability of success on the national registry exam using mock examinations. The mock examination used was a widely recognized and accessible assessment test. However, that specific test had a cutoff score that did not accurately predict the student pass rates of participants in the research. Based on the mock examination scores, a higher percentage of students taking the national registry exam for the first time should have had success on the first attempt. The selected students self-reported their first-time exam scores to the researchers. The researchers verified the scores using non-student-specific information published by the ARRT and the students' self-reported scores for programmatic use. Researchers compared the data and the expected outcome, based on the mock exam scores, but found that this did not align with the actual result after the student's first attempt on the national registry exam (Schmuck & Cook, 2018). The mock exam was 77.8% correct at predicting first-time successes and failures (Schmuck & Cook, 2018).

Research conducted by Paschal et al. (1998) identified the most significant factor in predicting a successful outcome on the Magnetic Resonance Imaging (MRI) registry exam developed by the ARRT. The MRI exam can only be challenged if a candidate has completed an

established MRI program, has been registered as a radiologic technologist, nuclear medicine technologist, or radiation therapist for at least one year. The researcher limited the participants to only candidates registered as radiologic technologists, R.T.(R)'s, for one year (Paschal et al., 1998).

Several factors also played a role in the success of R.T.(R)'s on the test, such as the type of training in MRI, hours of formal training in MRI, years of experience in MRI, hours per week worked in MRI, and the number of MRI exams performed each week, and lastly their success rate on the R.T.(R) exam (Paschal et al., 1998). The research results were that work experience in MRI and training in MRI were minimally related to the success of the ARRT's MRI examination. The prior success of candidates on the national registry exam was the most significant factor in predicting success on the MRI exam (Paschal et al., 1998).

Researching the specific topic of the LXMO exam's successful pass rate and directly correlating that with the national registry pass rate is the primary question in this research. Exam pass rates between LXMO and national registry candidates are comparable to those of successful LVNs and RNs. In research conducted on predicting pass rates for students taking both the NCLEX-PN and NCLEX-RN exams, focusing solely on exam success, only one study has been found that directly relates to this study's focus on pass rates as the sole measure of success.

In the study conducted by Benefiel (2011), four separate models were used to determine predictors of success and failure for RN students on the NCLEX-RN exam. The first model included traditional and contract students and their first-semester GPA and TEAS composite scores (Benefiel, 2011). The second model included the same variables as the first, except they used the TEAS subset scores instead of the composite scores (Benefiel, 2011). The third model

only included LVN-to-RN students (Benefiel, 2011). Lastly, the fourth model included all students minus TEAS variables.

Completing the research by examining Model 3 for this study's research needs demonstrated that the LVN to RN students had predicted pass rates of 100% (Benefiel, 2011). In summary, students who completed the NCLEX-PN exam at the end of their education and were successful later returned to school to become an RN and were 100% successful on their NCLEX-RN exam. This trend of passing an exam, such as the NCLEX-PN exam with a limited scope in nursing, led to 100% success on the NCLEX-RN after completing an educational track for the RN with a much broader scope in nursing (Benefiel, 2011).

Through numerous comprehensive searches, this Benefiel (2011) study is the only one found to be comparable to radiologic technology in any other allied health-related field. Benefiel's (2011) research supports this study's research question regarding the limited scope of the LXMO certification and the need to successfully pass the broader scope of the national registry exam to become a registered radiologic technologist.

In research conducted by Schmuck & Cook (2018), the mock examinations are generally completed in a classroom on campus or a clinical setting where the student is comfortable and familiar with the surroundings and other individuals involved. Schmuck & Cook (2018) do not directly state the environment in which the mock examinations were taken, so that assumption was made.

In Benefiel's (2011) research, the LVN students took the NCLEX-PN at a testing center with an unfamiliar environment, as did the RN students. The added stress of an unknown situation makes the LVN to RN testing and transition between degrees as close to the LXMO and R.T.(R) transition as possible, outside of collecting primary data. Lastly, the LVN and the

LXMO certifications in their respective fields are similar. The LVN and LXMO certifications are considered valid in their respective fields, but have a limited scope in operations. Similarly, RNs and R.T.(R) s have the full scope of practice in their respective fields upon certification.

**Current Situation**

The literature review will focus on recent articles related to the study's primary construct, utilizing a summative assessment as a formative evaluation. Research on the LXMO exam and the national registry exam was reviewed based on articles related to licensure exam success in other health professions, such as nursing, optometry, occupational therapy, and physical therapy.

The medical imaging profession currently faces extreme workforce challenges. According to the 2024 Consensus Committee report (ASRT, 2024), vacancy rates across all imaging and therapeutic disciplines have reached their highest levels since tracking began in 2003. For example, the radiographer vacancy rate in 2023 reached an all-time high of 18.1%, nearly triple the 6.2% rate reported in 2021. Similar dramatic increases were seen across other modalities:

- Cardiovascular interventional technology increased from 7.1% to 18.6%
- Computed tomography increased from 8.7% to 17.7%
- Sonography increased from 6.9% to 16.7%
- Magnetic resonance imaging increased from 8.7% to 16.2%
- Nuclear medicine increased from 4.2% to 14.5%
- Mammography increased from 4.3% to 13.6%

These staffing shortages have significant implications for both patient care and professional burnout. The 2024 Professional Workforce Survey reveals widespread symptoms of

burnout, with over half of workers experiencing emotional exhaustion multiple times a month and nearly 57% feeling underappreciated – indicators of the early to middle stages of burnout syndrome. Emotional exhaustion represents a more profound psychological depletion beyond normal tiredness, while feeling underappreciated creates an effort-reward imbalance that accelerates the burnout process. These interconnected issues suggest systemic workplace problems rather than individual struggles, as burnout develops when chronic stress combines with a lack of recognition and support. The health implications extend beyond job dissatisfaction to include depression, anxiety, cardiovascular issues, and weakened immunity, making this a significant health concern. When the majority of the professional workforce exhibits these symptoms, it indicates structural problems with how work is organized and valued, requiring organizational rather than individual solutions. This widespread burnout has contributed to high turnover rates, with 70% of survey respondents reporting staff departures from their departments in the previous year. The most commonly cited reasons for leaving included:

- Moving to another facility (80.9%)
- Burnout (35.0%)
- Retirement (21.4%)
- Family issues (16.3%)

Healthcare facilities have increasingly relied on temporary staffing solutions to address these shortages. The Consensus Committee found that 34% of departments now utilize temporary or traveling staff to fill vacancies, with 18.9% of these facilities reporting that temporary staff account for more than 20% of their positions (ASRT, 2024). This reliance on

temporary workers can affect continuity of care and place additional strain on permanent staff members.

### *Student-Centered Learning and Clinical Education*

Recent research conducted by Edwards (2023) has found that student-centered learning (SCL) is becoming increasingly prevalent in higher education. Students tend to have higher learning rates, motivation, and performance in all aspects of learning when taught using the SCL method. Since the inception of their formal education, Radiologic technology programs have consistently implemented SCL through the clinical rotation component and their didactic laboratory training. Edwards (2023) emphasizes that when students take a more active role and assume control over their learning, they exhibit higher levels of active participation and improved content retention. As participation and retention of content are retained at a higher level, academic performance in both the didactic and clinical settings is achieved (Edwards, 2023).

Higher rates of SCL will ultimately lead to more proficient students who can challenge the LXMO exam and become active participants, in a limited capacity, in the clinical setting through independent exam practice while building self-confidence, solidifying their positioning skills, increasing their patient care knowledge, and helping to alleviate the department's shortage of radiologic technologists.

### *Clinical Competency Evaluation and Performance*

Lenards (2020) found no significant differences in GPA or program effectiveness between graduates of the medical dosimetry program with a radiation therapy certification (RTT) and those without (non-RTT). However, when examining the statistics of students who did not graduate from the medical dosimetrist program or failed the medical dosimetry board exam the

first time, non-RTT students were significantly more prevalent (Lenards, 2020). It was also noted that non-RTT students needed more initial training and supervision, depending on their prior degrees upon hire at their first job (Lenards, 2020).

The information in the study completed by Lenards (2020) is comparable to that of students who are LXMO certified before challenging the national registry exam. Challenging the LXMO exam requires students to demonstrate both didactic and clinical knowledge in a limited capacity and demonstrate it on an unbiased exam in a standard testing environment. The mastery of program content to that point and the self-confidence gained will lead to higher first-time pass rates for students challenging the national registry exam. According to Lenards (2020), passing a limited prior exam will decrease initial training upon hire, and department supervisors will allow independent work more quickly. Experience and knowledge of both didactic and clinical content will produce successful, workforce-ready employees.

Newkirk et al. (2020) state that deliberate practice and repetition of a skill prepare for future challenges. When a problem is encountered in a previously experienced situation, the ability to handle it is determined by how well-equipped those in the situation are. This familiarity applies to both the mental and physical aspects of the task (Newkirk et al., 2020). By repeatedly simulating an experience, such as taking mock exams in a specific environment, we become accustomed to the situation. By combining the task with its surroundings, this comprehensive familiarity enhances performance when facing real-world challenges (Newkirk et al., 2020).

Research by Newkirk et al. (2020) found that administering mock exams to medical residents annually during their residency positively correlates with higher success rates on the medical certifying exam at the end of the three-year residency. This research hypothesis was confirmed as accurate following a ten-year study (Newkirk et al., 2020).

These results suggest that mock exams can help students achieve a higher success rate on their final certification exam. The mock exam process in the Newkirk et al. (2020) research will be consistent with the correlation of the LXMO exam in preparation for students to have a higher success rate on the national registry exam.

***Standardized Testing and Academic Success***

Research conducted by Harris (2018) determined that the high success rates of newly hired, entry-level registered radiologic technologists depended on the quality of the competency-based clinical component of the education program attended and an effective mentoring program during the clinical experience. This demonstrated that the entry-level career success of radiologic technologists is heavily reliant on the comprehensiveness of their clinical experience during training (Harris, 2018). A solid clinical experience begins with staff radiologic technologists and the resources to train students effectively. In this instance, the primary resources are the staff technologists with time to train. The nationwide staffing shortages are currently limiting the resources of staff radiologic technologists, as they do not have adequate time to mentor and train students.

Implementing LXMO certification of radiologic technology students during their educational program would ease the burden of staff radiologic technologists who must dedicate equal time to all students. The LXMO certification would enable the student to work independently within a limited scope, thereby relieving the pressure to train each student and allowing the focus to be primarily on training novice, non-certified students with direct supervision and LXMO-certified students with indirect supervision.

Occupational Therapy (OT) has developed a set of three assessment exams, including the Occupational Therapy Knowledge Exam (OTKE), which was created by the National Board for

Certification in Occupational Therapy (NBCOT). These three assessment exams are embedded and administered at specific curriculum junctures in OT programs (Kurowski-Burt et al., 2020). Since embedding the OTKE, OT students' pass rates on the NBCOT have been directly related to yielding a higher pass rate (Kurowski-Burt et al., 2020).

In a comprehensive three-year study, Kurowski-Burt et al. (2020) explored the predictive value of the OTKE for success on the NBCOT exam. The research revealed a similarity between the OTKE pass rate (85.27%) and the NBCOT pass rate (85.08%) during the studied period. Despite considering factors such as ACT scores, program GPA, and fieldwork performance, the study's findings underscored the OTKE as the most significant correlational factor on first-time NBCOT exam pass rates (Kurowski-Burt et al., 2020). This underscores the OTKE's role as a reliable predictor of success on the NBCOT exam, theoretically paving the way for its integration into the radiologic technology program's curriculum as a tool to predict and enhance first-time pass rates on the national registry exam.

Additional research conducted by Baldwin (2021) is determining if an Academic Practice Examination and Assessment Tool (APEAT), a formative assessment for physical therapy students administered by the Federation of State Boards of Physical Therapy, is an adequate tool for determining a correlation of success on the National Physical Therapy Examination (NPTE), also administered by the Federation of State Boards of Physical Therapy. The APEAT is a formative assessment that physical therapy students can take. If a score over 600 is achieved, a positive correlation with a passing score on the NPTE would be predicted. Research examined the correlation between the APEAT and NPTE, two exams administered by the same organization (Baldwin, 2021). This ongoing research on the correlation between the APEAT and NPTE, similar to the current study being conducted with LXMO certification and the national

registry exam, intends to demonstrate the existence of a correlation. The result of the APEAT formative assessment correlates positively with the success rate of the NPTE, but exhibits a weak predictive correlation with success (Baldwin, 2021).

Optometric Education (2021) states that standardized knowledge assessments are administered in controlled environments, allowing for student performance comparisons independent of external factors. While research across all medical fields remains limited regarding the accuracy of standardized tests in predicting success on final licensing or certification exams, there is demonstrated predictability across many professional medical degrees. This predictive potential offer hope for future medical education applications; however, the limited scope of existing studies highlights significant gaps in our understanding and underscores the need for more comprehensive research.

Research completed by Wafford et al. (2023) concludes that implementing a comprehensive exam for Medical Laboratory Science (MLS) students correlated to a higher success rate on the Board of Certification (BOC) exam. Results were compared before and after implementing the comprehensive student exam, and the results were precise in that implementation of the comprehensive exam before program completion accurately predicted each student's outcome on the BOC (Wafford et al., 2023).

The effectiveness of the comprehensive exam was mainly due to the in-depth and concurrent review that students needed to complete before challenging the BOC, in case they failed it (Wafford et al., 2023). This sequence of pre-test/post-test aligns with research conducted on the LXMO exam, correlating it with the national registry exam, which is used to predict the overall success of the national registry exam.

### *Program Effectiveness and Board Exam Performance*

Research indicates that high-stakes requirements, incentives, and in-depth preparation are essential for improving student success rates on pharmacy standardized exams (Le et al., 2023). An examination of research conducted by Le et al. (2023) revealed that implementing Pharmacy Curriculum Outcomes Assessment (PCOA) exams resulted in higher success rates on the North American Pharmacist Licensure Examination (NAPLEX). Research has shown that students who face high-stakes requirements perform better when adequately prepared before the exam (Le et al., 2023). The study examined two cohorts of students before the PCOA became a programmatic requirement, which was previously optional, and three cohorts after it became a graduation requirement. The success rates improved for all three cohorts after the PCOA became a requirement to pass the NAPLEX by a range of 11% to 18% (Le et al., 2023). Another factor considered in this research was student GPA; however, the PCOA requirement was determined to be the most significant factor in predicting NAPLEX success (Le et al., 2023).

Le et al. (2023) state that the high-stakes PCOA forced students to take the NAPLEX more seriously. If students had performed poorly on the PCOA, they would have been required to complete a remediation plan provided by the school (Le et al., 2023). Adding extra pressure on students before program completion forces them to review content and take program requirements, the PCOA, seriously.

Recent research by Brown (2023) discusses the JRCERT requirement that a 75% pass rate on the national registry exam be achieved for JRCERT-accredited programs to remain in programmatic compliance. Brown (2023) discusses ways to enhance programs' national registry exam pass rates by promoting self-efficacy, specifically through providing students with autonomy support, competence support, and relational support. All of these supports, as

previously mentioned, should be provided to the student through interaction with program faculty, both didactically and clinically (Brown, 2023). According to Bandura (1997), self-efficacy is "people's agency and cognition are important in shaping their behavior." In summary, students need to feel comfortable enough to express their needs to faculty in order to succeed in the program and pass the national registry exam. Through autonomy, competence, and relational support, instructors must be available to students to meet these needs, as meeting these needs leads to a higher level of self-efficacy in students (Brown, 2023).

Brown (2023) states that combining low-stakes information feedback assessments throughout the educational program is equally as vital as high-stakes assessment feedback through various testing methods. Additionally, external stressors may hinder student programmatic performance; therefore, embedding high-stakes situations into didactic learning will aid students in preparing for the national registry exam by familiarizing them with these experiences and helping them handle the related pressures (Brown, 2023). Ultimately, Brown (2023) suggests that programmatic faculty should meet each student's self-efficacy needs in whatever way they need to be met by providing continual reinforcement and feedback on student performance.

The natural pressure for students to challenge the national registry exam modifies situational circumstances. If the student were exposed to a similar experience by challenging the LXMO exam during the program in a high-pressure environment testing center, it would seem natural that the familiarity with that environment on the day the student challenges the national registry exam would be lessened. Through self-efficacy and the confirmation of performance during the program, students would acquire the necessary skills, both didactically and clinically,

to pass the high-stakes national registry exam for which the program has prepared them (Brown, 2023).

## Theoretical Framework Literature

According to Creswell and Creswell (2023), theoretical frameworks predict the expected relationship among variables to explain this expectation or prediction. As established during this literature review, a gap in germane or current research is evident. The researcher employed CLT to frame and substantiate the existing limited research.

### *Cognitive Load Theory*

CLT was founded on schema acquisition (Sweller, 1988). A schema is the process of developing and storing organized patterns of thought or behavior that categorize information and relationships among data. These mental processes clarify and interpret new information based on prior knowledge and experiences (Sweller, 1988). Schemas enable learning by organizing information, facilitating an understanding of new concepts, reducing cognitive load when new information is presented, and aiding the transfer of knowledge to new situations. Sweller (1988) determined schema acquisition as a primary goal of learning; as learners develop complex and automated schemas, more complicated tasks take less cognitive effort.

CLT lends itself to differentiating experts and novices when presented with the same information. Experts process information more quickly and effectively than novices. Once processing is expedited to a high level, the information is transferred from working memory (WM) to long-term memory (LTM) (Sweller, 1988).

As research progressed over the next two decades, CLT further explained the role distinctions of WM and LTM. Cognitive load occurs when a new bolus of information is presented, and initial schema or learning starts. Limited learning occurs when the working

memory (WM) is challenged with a significant cognitive load (Sweller et al., 2019). If present in smaller amounts, the WM processes cognitive load information, has time to group information into categories, and establishes patterns of cognitive functions. Effective learning and knowledge transfer are achieved by reducing irrelevant cognitive processing, optimizing learning-related activities, and sustaining overall cognitive demands while limiting a learner's mental capacity (Sweller, 2019; van Merriënboer et al., 2006).

Research progressed, and cognitive load was further categorized as extraneous, intrinsic, and germane cognitive loads (van Merriënboer & Sweller, 2010). Extraneous load is defined as gathering different sources of information and categorizing the data into understandable groupings to decrease repetition (van Merriënboer & Sweller, 2010). Intrinsic load filters information in a simple to more complex pattern (van Merriënboer & Sweller, 2010). Lastly, a germane load is learning capitalized by diversifying tasks, introducing challenges within context, and encouraging learners to prove their understanding (van Merriënboer & Sweller, 2010). These guidelines are frequently used in the education of healthcare professionals, such as radiologic technology students. All three guidelines form the foundation of medical education, helping learners understand what information they possess and lack, indicating whether the learner is a novice or an expert.

Van Merriënboer et al. (2006) determined that balancing an intrinsic load to force cognitive connections as students transition from novice to expert learners is valuable in developing and fostering genuine learning. This research describes how assigning overly complex tasks to novice learners will ultimately hinder their ability to transfer information or training. The transition from novice to expert learners is most effective when tasks are varied and contain some familiar information. This altered but similar task increases learner transfer of

information most effectively and efficiently (van Merriënboer et al., 2006). Additionally, van Merriënboer et al. (2006) suggest that providing learners with limited guidance and feedback as they transition from novice to expert is recommended to promote their critical thinking and problem-solving abilities.

Louw's research (2021) suggests that increasing cognitive load in radiologic technology students is possible through the use of high-fidelity simulations, which can enhance critical thinking. Increasing students' critical thinking through either simulation or clinical experience builds a high cognitive load through repetition and task prioritization. The WM develops a higher level of prioritization to complete entire scenarios, and this learning is transferred to LTM (Louw, 2021). Repetition of high-fidelity situations enhances students' critical thinking skills and, over time, improves cognitive prioritization processing from working memory (WM) to long-term memory (LTM) (Louw, 2021).

CLT illustrates the learning process through several steps. It begins by presenting information to the WM, categorizing the data within the WM, and building connections through single-task completion. Ultimately, categorized information is transferred to the LTM after numerous high-fidelity, low-cognitive-load scenarios have been encountered. CLT validates the methodical process necessary to demonstrate that learning has occurred through permanent transfer to LTM.

Students demonstrate their knowledge through active clinical testing to assess that information has been processed and retained in the LTM. They also objectively prove their knowledge through a standardized evaluation, the LXMO exam. This dual approach allows for a comprehensive assessment: program faculty evaluate students' practical skills, while the standardized LXMO exam provides an unbiased measure of their theoretical knowledge.

**Methodology Literature**

This study investigated the correlation between the LXMO and national registry exams. According to Adu and Miles (2024), correlational research aims to establish a positive, negative, strong, or weak relationship, but it must demonstrate statistical significance. Research studies, such as those by Benefiel (2011), Paschal et al. (1998), and Baldwin (2021), have reviewed factors beyond the correlation. This research employs correlation analysis to investigate whether passing the LXMO exam affects the first-time pass rate of the national registry exam.

**Research Design Literature**

The study aimed to investigate the correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota. Francis Galton initially discovered correlation in 1888 (Stigler, 1989). Karl Pearson expanded upon that discovery and developed the mathematical formula for statistically calculating and measuring correlation (Stigler, 1989). The equation Pearson developed is now known as the Pearson correlation coefficient, a statistical tool that measures the strength of the relationship between two variables (Stigler, 1989).

The most relevant research supporting this study uses correlational methods to demonstrate how one element affects another. Several studies have employed correlational designs as a foundational research approach, demonstrating their effectiveness in examining relationships between variables in educational assessment and predicting academic success. Research conducted by Baldwin (2021) employs a quantitative correlation approach, measured retrospectively, to analyze the relationship between a limited-scope pre-test in physical therapy and a national physical therapy certification post-test, examining both independent and dependent variables. Baldwin (2021) stated that the correlation research method was used

because the independent variable could not be manipulated; however, this method would still determine a predictive relationship between the two variables. Baldwin's (2021) quantitative correlation research method was designed similarly to this research.

Benefiel's (2011) research, based on the correlation between the LVN and RN NCLEX licensing exams required for each profession, shows a relationship between the success rate on the NCLEX-PN exam and the succeeding NCLEX-RN exam. Benefiel (2011) used other factors in this research, but all the research was analyzed using a bivariate correlational methodology. Benefiel's (2011) research used other factors such as pre-nursing GPA and type of student (traditional, LVN to RN, transfer), standardized pre-admission testing results, number of attempts on the standardized pre-admission tests, first semester GPA, nursing GPA, number of course repeats, and time from graduation to NCLEX-RN. Benefiel (2011) employed more factors in the established research than this study, but a correlational methodology was used throughout.

Paschal et al. (1998) used a multiple regression correlation research design. This design determined the significance of the correlational relationships between all the dependent variables measured during the research. The relationship with the strongest statistical correlation was found to be a success on the national registry exam for radiologic technology as a predictor of success on the MRI registry exam (Paschal et al., 1998). Although conducted under the umbrella of radiology, Paschal et al.'s (1998) research is not directly related to the LXMO exam and the predictability of the national registry exam. The MRI certification is a separate branch of radiology and does not involve a pre-test or post-test scenario, unlike the LXMO and national registry exams.

**Summary**

Chapter II presents a comprehensive literature review on predictors of success in radiologic technology programs and certification exams, highlighting a significant research gap in the relationship between LXMO and national registry exam performance. While existing research has explored features such as GPA and prerequisites, no studies have explored the potential value of the LXMO exam—an existing ARRT assessment tool—as a predictor of success on the national registry exam. Research from related healthcare fields demonstrates correlations between preliminary exam performance and certification exam success. CLT provides theoretical support, suggesting that prior exam experience facilitates knowledge transfer and improved performance on subsequent exams. The literature indicates that standardized assessments during programs can predict and enhance certification exam pass rates. The study seeks to address the identified research gap by examining the predictive value of the LXMO exam and its potential applications in radiologic technology education and certification.

Chapter 3 will discuss research methodology and processes applied to this study, including the selection of participants, the instruments utilized, data collection, data analysis, and ethical considerations. Chapter 4 will evaluate and present data as described in Chapter 3. Lastly, Chapter 5 will discuss the study's implications and recommendations for further research.

# Chapter III: Research Methodology

## Introduction

This chapter is dedicated to the research methodology employed in a correlational study of radiologic technology education. The research focuses on the relationship between the success of radiologic technology students on the national registry exam and their prior achievements on the Limited X-ray Machine Operator (LXMO) exam. The methods are designed to clarify how one successful exam attempt can pave the way for another, shedding light on a significant aspect of radiologic technology education. Both exams cover similar content, but the first focuses on specific concepts and skills in general radiologic technology. At the same time, the second approach has a broader and deeper perspective on the entire field of radiologic technology. The second is aligned with the national registry exam. Chapter 3 provides a detailed explanation of the method used to investigate the correlation between these two factors.

It is unknown whether there is a correlation between the success of radiologic technology students in passing the LXMO exam and their subsequent performance on the national registry exam. Limited research will be conducted in similar healthcare programs. However, this exploratory study is among the first to investigate this correlation, contributing initial insight into radiologic technology education.

## Research Method and Design

A quantitative approach, utilizing measured data, is preferable when research focuses on uncovering factors that shape an outcome and explain the connections between those variables (Creswell & Creswell, 2023). The MDH and the ARRT supply data. Data is analyzed upon receiving the final data set from the ARRT to establish connections between the LXMO pass rate and the first-time pass rate of the national registry exam, serving as the research variables (Creswell & Creswell, 2023).

This methodological approach is further supported by recent research in the field. The 2024 Consensus Committee on the Future of Medical Imaging and Radiation Therapy successfully employs a similar secondary data analysis approach by combining datasets from multiple professional organizations to assess workforce trends and educational outcomes (ASRT, 2024). Their research demonstrates the validity of using organizations like MDH and ARRT datasets to analyze the relationships between certification examinations and professional outcomes. This precedent supports the current study's methodology of examining correlations between LXMO and national registry exam performance through secondary data analysis.

- **Independent variable:** passing the limited X-ray machine operator state licensing exam.
- **Dependent variable:** passing the national registry exam.

This study is non-experimental, as it does not involve manipulating variables. Instead, it is a correlational study that examines two variables related to the exam success of radiologic technology students. As Creswell and Creswell (2023) outline, this design aligns with a non-experimental approach. The primary focus of this chapter is on the research methodology, participant description, data collection, and analysis methods, as well as establishing the initial research on this topic, demonstrating the thoroughness and rigor of the approach.

The LXMO examinees and the results of the national registry exam contain valuable data that have yet to be researched. The ARRT creates both the LXMO exam and the national registry exam, and it represents a logical profession for students by challenging the limited exam before taking the comprehensive exam, thereby gaining experience with all aspects of exam-taking outside of a school-established, familiar environment. According to Brown (2023), programs should provide students with autonomy, competence, and relational support throughout their

participation in the program. The confidence and self-efficacy developed from challenging the LXMO exam indirectly reinforce these supports.

The correlation approach to the secondary data collected is the most representative way to evaluate a single variable and demonstrate the potential importance of the LXMO exam and its effect on the outcome of the national registry exam. Numerical data and the possible correlation minimize the bias incorporated with standardized testing in the case of both exams studied. The main objective of this research is to determine if a correlation exists between the two exams and whether programs should consider the LXMO exam as a pathway to obtaining status as a registered radiologic technologist by successfully passing the LXMO exam.

The use of secondary data research has recently increased (Sun & Lipsitz, 2018). According to Dagan & Wilkins (2023), accessing secondary data sets can expand our understanding of large-scale information by refining detailed information from the large dataset, while still ensuring the quality and integrity of the data.

A qualitative method design would not produce adequate data for this study. Kyngäs (2020) describes qualitative research as an approach used when the event already exists and the researcher seeks to determine the potential causes of a complex situation. Qualitative research would add further understanding to the topic; however, these data are not readily available. A mixed-methods approach was unnecessary because the research question is analyzed to determine the most suitable research method for finding an answer. A mixed-methods study uses quantitative and qualitative methodologies, enabling a deeper understanding of complex phenomena. Still, the primary purpose of this research is not to investigate multiple variables, but rather to initiate research on this topic in general (Manzoor, 2020).

## Research Questions/Hypotheses

The research question guiding this quantitative survey method study was:

RQ1: What is the relationship between success on the Limited X-Ray Machine Operator (LXMO) exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota?

H1: There is a significant positive correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota.

H1N: There is no significant correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota.

## Population and Sample Selection

The study population includes certified individuals who completed the LXMO exam between 2000 and 2024 in Minnesota-based programs. These data are publicly available from MDH. This probability-based technique helps ensure adequate representation of radiologic technology students, both those with and without prior success on an LXMO exam (Keusch, 2023). The researcher obtains all available data from MDH and submits that list to the ARRT. Due to the ARRT's privacy policy, they are not permitted to disclose the names of registrants. Therefore, their review team conducts the comparison and provides only the total numbers to be used as the dataset. One set of numbers represents the total number of individuals who took the LXMO and the national registry exams. In contrast, the other set of numbers indicates the

number of those individuals who passed the national registry exam on their first attempt after taking the LXMO exam.

### *Sample Size*

The study's target group, encompassing all potential participants from which researchers can draw a representative sample, is known as the population (Creswell & Creswell, 2023). The population comprises all radiologic technology students eligible for the LXMO exam. Creswell and Creswell (2023) state that an adequate sample size ensures that results reflect the population within a selected margin of error and is sufficient to justify potential correlations in this study. The study sample consists of all Minnesota candidates who have completed the LXMO and national registry examinations, with data collected from 100% of these eligible individuals. As stated, all the data used for this research is secondary. This study ensures participant safety and is designed to be reproducible by other researchers.

It is important to note that preliminary data analysis reveals a relatively small sample of individuals (n = 24) who have taken the LXMO and national registry exams over the 25 years (2000-2024). While this represents the complete population of interest rather than a sample, the limited number of cases may affect the statistical power of correlation analyses and the generalizability of findings. This limitation reflects the current state of LXMO certification adoption among radiologic technology students in Minnesota, highlighting the exploratory nature of this research. Examining this complete population provides valuable initial insights into this previously unstudied relationship despite this restriction.

## Informed Consent and Confidentiality

The researcher receives approval from the institution's IRB before obtaining data (See Appendix A). Once IRB approval is obtained, all required information is requested from the

ARRT. Data from a public repository maintained by MDH has already been obtained. MDH requires all parties applying to take the LXMO exam in Minnesota to sign a Tennessen Warning. The Tennessen Warning states that when individuals become licensed, certified, registered, or another form of approval authorized by statute or rule, all information in the application becomes public, except the social security number (See Appendix B) (MDH, 2021). The researcher adheres to protocols defined by the institutional IRB. This protocol outlines the researcher's exempt status for this research and requires the researcher to submit any changes made during the research to the IRB. No identifying data were used when reported throughout this study (Adu & Miles, 2024).

**Instrumentation**

Following IRB approval, public data from 2000 to 2024, as listed by the MDH, identifies each person who has passed the LXMO exam. The ARRT utilizes LXMO-certified individuals and cross-references their names with the list of first-time pass attempts of radiologic technologists in Minnesota, which provides the numbers used for this research. Due to the secondary nature of the data collected for the study, no additional data are necessary to supplement this research.

The secondary data collected from the ARRT are only numbers, so this study poses no risk to participants. If a data breach were to happen, no individual names could be traced back to specific participants or programs. Due to an ARRT privacy policy, there are no risks to participants. No personal or identifying data is received from the ARRT, and data received from the MDH is public information.

## Data Collection

Due to the nature of research conducted to collect secondary data, the institution's IRB determines that no harm is caused to the individual data acquired. Since all the data used in the research was secondary, the replicability of this study will be possible if the same process is followed.

Recent research supports the use of secondary data from MDH and ARRT. The 2024 Consensus Committee on the Future of Medical Imaging and Radiation Therapy utilizes similar secondary datasets to examine trends in certification and the workforce (ASRT, 2024). Their research demonstrates that these organizations maintain comprehensive, reliable databases that can be used to observe relationships between certification examinations and professional outcomes. For instance, the MDH data analysis accurately tracks certification status, while ARRT data offers reliable examination performance metrics. This precedent supports this study's approach to data collection using these institutional datasets.

To ensure data quality and reliability, this study follows similar procedural safeguards as those employed by the American Society of Radiologic Technologists (ASRT, 2024). Additionally, any identifying information is removed before analysis to maintain participant confidentiality while preserving the statistical validity of the examination performance data.

## Data Analysis

This quantitative survey study examines the relationship between radiologic technology students' success in passing the national registry exam and their prior performance in passing the LXMO exam. Data will be collected through secondary measures. Target population information is gathered from a 25-year data set on students in Minnesota.

Research guiding this quantitative survey method study is:

RQ1: What is the relationship between success on the Limited X-Ray Machine Operator (LXMO) exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota?

The correlational analysis is used to test the hypothesis.

**Limitations**

Results obtained through secondary data analysis have inherent limitations when using that data. Limitations include ensuring the ethical collection of primary research and reviewing it through the perspective of a qualified expert (O'Connor, 2020).

A limitation to adding the LXMO exam to program requirements is access to the exam. Currently, only 34 states use the ARRT LXMO exam to certify people to administer radiation (ASRT, 2024). Implementing this exam into radiography programs would not be equitable from an accreditation standpoint. It cannot be mandatory by any external agency if state law does not allow this exam to be administered. Second, the financial burdens of taking the exam and transportation to an exam center may hinder students. However, there are potential solutions to these issues. It would be most beneficial if programs could embed exam costs and arrange transportation for students to an exam center.

Additional research limitations include the limited number of qualified individuals and the study's cross-sectional design. This limits the ability to establish causality and observe changes over time. Another study limitation is self-selection bias, where students chose to take the LXMO exam, indicating different characteristics or motivations than those who do not, which could potentially skew the results. Lastly, although practical, reliance on only secondary

data from MDH and ARRT may have limited the types of analyses possible and the specific variables available for study.

**Delimitations**

If a government agency collects the data, its traditional approach typically involves using descriptive and inferential statistics throughout its datasets (O'Connor, 2020). Research delimitations include the specificity of a relationship between the LXMO exam and the national registry exam's first-time pass rate. Secondary data collected from MDH and ARRT quantify statistical data and demonstrate a potential relationship. A geographical focus on only programs in Minnesota will also add to the study's delimitations. The research employs a quantitative approach; however, qualitative insights may be overlooked due to the collection methods and reliance on secondary data.

**Summary**

Chapter 3 outlines a quantitative correlational study methodology. Research examines the relationship between radiologic technology students' passing the national registry exam and their prior success on the LXMO exam. Secondary datasets are collected from the MDH and the ARRT, allowing for data analysis, including correlations, and are completed upon receipt of the data. Chapter 4 evaluates and presents data as described in Chapter 3. Lastly, Chapter 5 discusses study implications and recommendations for further research.

# Chapter IV: Analysis and Results

## Introduction

The LXMO exam has been studied as a possible supporting component for students enrolled in radiologic technology programs in Minnesota. This research has examined the relationship between taking the LXMO exam and subsequent performance on the national registry exam. Data collected between 2000 and 2024 identified 24 Minnesota students who had taken the LXMO and national registry exams. Among these students, 70.8% passed the national registry exam on their first attempt. This pass rate differed from the national first-time pass rate (85.2%) and Minnesota's first-time pass rate (83%) for 2024, raising important questions about the relationship between LXMO-certified and national registry exam performance.

Despite this pass-rate difference, investigating the relationship between LXMO certification and radiologic technology program outcomes remained valuable. Understanding this relationship informs curriculum decisions and potentially impacts radiologic technology education in ways beyond pass rates alone. Examining this relationship has revealed other benefits that could justify the additional exam, despite the observed differences in pass rates.

Initiatives to integrate the LXMO exam into radiography programs in Minnesota face challenges such as cost, time, and the ability of LXMO-certified students to participate. At the same time, they are still enrolled in radiologic technology programs. This study analyzed ARRT data to better understand the relationship between LXMO certification and performance on the national registry exam, providing evidence to inform decisions about integrating LXMO certification into radiologic technology curricula.

## Research Question

Implementing the LXMO exam was found challenging due to the financial barriers for students and the time-consuming nature of the process for educators. This study investigated whether incorporating the LXMO exam into radiologic technology programs impacted first-time pass rates on the national registry exam. Secondary data collected from the MDH on LXMO examinees and ARRT-registered radiologic technologists and their first-time pass rate status on national registry exams demonstrated this trend (ARRT, 2024). Data was reviewed to analyze the impact of the LXMO exam on the first-time pass rate of the national registry exam among examinees in Minnesota.

RQ1: What is the relationship between success on the Limited X-Ray Machine Operator (LXMO) exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota?

H1: There is a significant positive correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota.

H1N: There is no significant correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota.

## Data Collection and Analysis

Qualitative, quantitative, and mixed-method approaches were considered to determine the methodology. Qualitative research aims to understand why and how people behave in specific

ways and their relationships (Safire & Dugan, 2021). Quantitative research seeks to explain patterns through statistical data analysis, while mixed methods integrate both qualitative and quantitative approaches for a holistic perspective (Safire & Dugan, 2021). A quantitative study was selected, and secondary data were used from two governmental organizations. Public information was obtained from the MDH with a list of all individuals who had obtained LXMO licensure in Minnesota between 2000 and 2024 (MDH, 2024). The ARRT Request Review Team requested an official letter stating IRB approval for the study and a list of names from MDH.

According to an ARRT privacy policy, researchers are not permitted to compare names. The ARRT was provided with a list of individuals who became licensed as LXMO between 2000 and 2024, and the ARRT Request Review Team analyzed the names. The ARRT Request Review Team then released pertinent, anonymous data to the researcher describing the number of individuals who had taken the LXMO exam and had a first-time pass rate on the national registry exam in Minnesota.

**National Registry Exam Scoring System**

Before presenting the findings, it is important to understand how the ARRT evaluates exam performance. The ARRT uses scaled scores (1-99) to report exam results (Annual Exam Report, 2023). This approach represented scores at the same performance level regardless of a candidate's exam version. Scaled scoring eliminates potential penalties for candidates who receive slightly more difficult exam forms, allowing for a meaningful comparison of results across different versions. On the national registry exam, a scaled score of 75, the required

passing scaled score, did not equate to a candidate answering 75% of the test items correctly (Annual Exam Report, 2023).

**National Registry Exam Performance Data**

Nationally, the first-time pass rate on the registry exam was 85.2% in 2024, meaning 15.6% of first-time examinees received a scaled score of 74 or below (Annual Exam Report, 2023). Of 11,489 first-time candidates who took the national registry exam in 2023, 1,792 were unsuccessful on their first attempt (Annual Exam Report, 2023). Across all test takers nationwide, the average exam pass rate has been 87% over the past eleven years (Annual Exam Report, 2014-2024).

**Minnesota Registry Exam Performance Data**

In Minnesota, 288 candidates took the national registry exam in 2024 (Annual Exam Report, 2024). Minnesota's pass rate was 83%, slightly below the national average, resulting in 16.4% of first-time national examinees not passing the exam (Annual Exam Report, 2023). This translates to 42 unsuccessful candidates in Minnesota in 2023.

If the national pass rate were applied to candidates who took the exam, an estimated 2,165 examinees would fail to pass the national registry exam in 2023 (Annual Exam Report, 2023). Given the existing worker shortage in radiologic technology, this number of unsuccessful candidates presents a significant challenge to the field.

**LXMO and National Registry Exam Relationship**

Table 1 summarizes the data provided by the ARRT concerning LXMO-certified individuals who subsequently took the national registry exam in Minnesota.

**Table 1** *LXMO Certification and National Registry Exam Performance Compared to National and State Averages (2000-2024)*

| Group | Total Examinees | Passed National Registry on First Attempt | Failed National Registry on First Attempt | First-Time Pass Rate |
|---|---|---|---|---|
| LXMO-Certified Students (MN) | 24 | 17 | 7 | 70.8% |
| All MN Examinees (2023) | 256 | 214 | 42 | 83% |
| National Examinees (2023). | 11,489 | 9,697 | 1,792 | 85.2% |

The ARRT data showed that 17 out of 24 candidates (70.8%) who had previously passed the LXMO exam also passed the national registry exam on their first attempt (ARRT Review Request Team, 2024). This is lower than the national exam first-time pass rate (85.2%) and Minnesota's first-time pass rate (83%) for 2024. It is also lower than the average national exam pass rate of 87% over the past eleven years (Annual Exam Report, 2014-2024).

**Data Analysis**

The data indicated that LXMO-certified individuals who subsequently took the national registry exam had a first-time pass rate of 70.8%. This finding contradicts the initial expectation that LXMO certification would improve national registry exam performance, as the observed pass rate (70.8%) is lower than both the national average (85.2%) and the Minnesota average (83%).

However, several important considerations must be acknowledged: the relatively small sample size of 24 individuals who took both exams over 25 years (2000-2024) limits the

statistical power and generalizability of these findings. The data do not account for potentially confounding variables such as the timing between the LXMO exam and the national registry exam, student academic performance metrics, program quality and characteristics, demographics, and other student characteristics. Establishing a causal relationship is difficult without a matched control group of students with similar characteristics who did not take the LXMO exam.

Given these limitations, the current data does not support the hypothesis that "there is a significant positive correlation between success on the LXMO exam and the first attempt pass rate on the national registry exam" (H1). The findings suggest that LXMO certification alone may not be a significant predictor of higher first-time pass rates on the national registry exam. A more robust analysis with a larger sample size would be needed to draw definitive conclusions.

## Results

The secondary data results indicate that 70.8% of Minnesota LXMO examinees who subsequently take the national registry exam pass on the first attempt (ARRT Review Request Team, 2024). The data shown in Table 1 includes 24 total LXMO examinees; of those, 17 passed the national registry exam on their first attempt (ARRT Review Request Team, 2024).

## Summary

Chapter IV summarized the findings and analyzed the data on the relationship between LXMO certification and first-time performance on the national registry exam. Although limited by sample size, the data indicate that LXMO-certified students had a 70.8% first-time pass rate on the national registry exam, which is lower than the national and Minnesota averages. Further

research with larger sample sizes and more robust methodologies would be necessary to establish definitive conclusions about this relationship. Chapter V presents an analysis of the results and discusses the research implications.

# Chapter V: Discussion and Conclusions

## Introduction

At the national level, conversations have been initiated among the ASRT and its constituents to promote the professionalism of radiologic technology (ASRT, 2024). Educators have encouraged students to obtain their bachelor's and master's degrees upon completing their radiography program to advance the field's technical designation to professional status, following the same path as the nationally recognized registered nurse designation. The field of radiologic technology faces numerous challenges, including worker shortages, a lack of consistent national-level legislation with guidance on licensure by state, an aging and retiring population, and the lingering effects of COVID-19 on healthcare in general.

Chapter V provides conclusions based on research findings on the impact of students taking the LXMO exam before the national registry exam. This conclusion will review the study's purpose, research questions, literature review, and findings. It will then present conclusions, a discussion, and recommendations for further research.

## Discussion and Conclusions

Educational programs should consider various factors when making curriculum changes, including the cost, time, and benefits to students and the program, the effectiveness of the change, and the overall value of the change to the program. However, the results of this research do not support a significant positive correlation between success on the LXMO exam and the first-attempt pass rate on the national registry exam. Data revealed that students who completed the LXMO exam before attempting the national registry exam achieved a 70.8% first-time pass rate, notably lower than the national averages of 85.2% and Minnesota's 83% for first-time test

takers. Several factors may help explain these results and should be considered when interpreting the data.

Factors such as sample size, timing between exams, student academic characteristics, demographic information, and variations in program quality are significant factors that may affect students' pass rates. More specifically, the LXMO exam is not currently required in any radiography program curriculum in Minnesota. The researcher had access to secondary data on students who became LXMO certified and subsequently took the national registry exam voluntarily. The voluntary nature of this exam introduces inherent selection bias; students who complete the exam may differ from those who do not in important ways. Additionally, students who opt to take the exam may differ in their performance when they take it during the program.

Beyond individual student factors, program-level variables may also influence the outcomes of the exams. First, test fatigue or overconfidence may influence students who have become LXMO certified, leading them to believe that they do not need to study as much or as in-depth for the national registry exam. Second, the student's study approach to the LXMO exam may have been more limited or focused in nature, which may not translate well to the studying required for the national registry exam, particularly in terms of its breadth or depth. Third, the timing between the two exams may vary between students. For example, suppose the LXMO and national registry exams are taken too closely together. In that case, it may not give the student adequate time to broaden their scope when transitioning from studying for the LXMO exam to the national registry exam. If the two exams are taken with too much time between them, it may lead to limitations in content retention.

In addition to test preparation approaches, the timing of the examination requires further consideration. Program quality may vary depending on their encouragement of their students to

take the LXMO exam, which could also lead to variations in results. The sample size of 24 in 25 years is too small to determine whether the observed results represented a genuine effect or simple random variation. The 25-year span of data collected in itself could pose many variations in educational curriculum and environmental challenges compared to more recent examinees. Since demographic data were not collected or shared in this study, we cannot assess how socioeconomic factors might influence students' decisions to take the optional LXMO exam, which incurs additional costs and is not required for program completion.

While the data did not support the hypothesized correlation, a deeper examination of these results reveals several important implications for radiologic technology education and practice. Data suggests that students who completed the LXMO exam before attempting the national registry exam in Minnesota had a lower success rate than those who only attempted the national registry exam upon completing their radiography program. The ASRT, in its 2024 white paper on the future of medical imaging, is exploring alternative ways to promote professionalism within our profession and potentially establish a pathway for growth within our field, similar to the model in nursing, where individuals progress from licensed practical nurse to registered nurse.

## Implications

This study does not demonstrate a correlation between pass rates on the national registry exam. Its theoretical and practical implications suggest subsequent steps for additional research.

### *Theoretical Implications*

According to Sweller (1988), CLT posits that working memory has a limited capacity, and effective learning occurs when information is transferred from working memory to long-term memory through structured experiences that manage cognitive load effectively. The first

hypothesis in this study suggested that experience with the LXMO exam would create a schema and knowledge structure that would reduce cognitive load when taking the national registry exam. However, acquired data showed a lower first-time pass rate (70.8%) for LXMO-certified students compared to national (85.2%) and Minnesota (83%) averages, suggesting a more complex relationship with CLT than initially theorized.

The lower pass rates suggest a complex relationship between limited-scope and comprehensive exam preparation that CLT helps explain through several interrelated mechanisms. Rather than the LXMO exam creating helpful mental frameworks that transfer to the national registry exam, it may establish narrow knowledge structures that create three potential problems: First, these limited structures may be insufficient for addressing the breadth of content on the national exam; second, according to van Merriënboer and Sweller's (2010) distinction between productive and unproductive cognitive load, the LXMO preparation may generate extra cognitive load that does not contribute positively to registry exam performance; and then, the timing between exams likely does not align with knowledge structure development principles of CLT.

This aligns with Louw's (2021) research on cognitive load in radiography education, which demonstrates that while high-fidelity situations can foster critical thinking that improves cognitive processing from working memory to long-term memory, the quality and structure of these experiences significantly impact whether knowledge is transferred positively. The LXMO exam was predicted to facilitate organized patterns of thought transferable to the national registry exam. However, the lower 70.8% pass rate indicates that this transfer process is more

complicated than initially hypothesized, with the possibility that LXMO preparation may establish competing or insufficiently comprehensive knowledge structures.

When analyzing the data with the predictive validity concept within CLT, the goal is to predict and perceive that the LXMO exam would positively correlate with national registry exam performance (Van Elk, 2021). However, the data showing a 70.8% pass rate for LXMO-certified students compared to higher national (85.2%) and Minnesota (83%) averages challenge this predictive relationship. Applying this concept to a specific educational context has proven unreliable enough to predict performance on related subsequent assessments. This is connected to Sweller's (1988) emphasis on how prior knowledge structures influence new learning situations, suggesting that how students organize and apply knowledge from the LXMO exam experience may not align predictively with the broader cognitive demands of the national registry exam in the straightforward manner initially hypothesized.

Lastly, examining the findings through Thorndike and Woodworth's transfer of learning theory, which applies knowledge and skills previously learned to a new situation, demonstrates the importance of applying knowledge across different assessment contexts (Haskell, 2004). The transfer of learning theory predicted that the LXMO exam experience would facilitate successful performance on the national registry exam by providing an experience in a familiar situation. Nevertheless, the lower pass rate among LXMO-certified students compared to national and state averages suggests that the transfer of learning has an adverse effect.

The negative transfer of learning between the two exams indicates that the experiences between the situations may be more superficial than substantive from a cognitive processing perspective. As Sweller et al. (2019) demonstrated in their research on cognitive architecture,

effective transfer depends not just on content similarity but also on how knowledge is structured and retrieved. These theoretical insights inform practical considerations for how LXMO certification might be most effectively implemented despite the unexpected exam performance outcome.

### *Practical Implications*

Although the research did not prove the stated hypothesis, it has many valuable attributes. If structured appropriately, integrating the LXMO exam into the radiography program curriculum may have positive correlations directly related to first-time national exam pass rates, provided that students take the LXMO exam at controlled points within the radiography curriculum. The limited dataset had the potential to skew the viability of the LXMO exam due to the previously mentioned theoretical implications.

Financial and logistical challenges pose potential barriers to students, including additional costs to their education and the proximity to a testing center that administers the LXMO exam. In addition to the financial and logistical challenges, the LXMO exam or a similar exam created by an individual state lacks consistency on a national level. State legislation varies across the United States, and only 34 states use the ARRT-created LXMO exam; therefore, it would be impossible to implement this exam in all radiography programs.

Despite the lower national registry exam pass rates among LXMO-certified students, there remain practical benefits for certified students in educational programs. Regarding supervision policies, JRCERT requires direct supervision until students demonstrate competence through program-established competencies; LXMO certification could provide an objective,

standardized measure of competence that justifies the privileges of indirect supervision. The LXMO certification might potentially be used to validate students' abilities for indirect supervision privileges. It could also serve as a program assessment tool, allowing students more autonomy to practice independently within their clinical setting.

As Nieuwenhuis et al. (2023) discussed, prior exposure to information and current physiological state are essential aspects of learning processes. This suggests that the structured independence gained through LXMO certification could enhance student confidence and clinical decision-making abilities regardless of ultimate registry exam performance.

LXMO certification presents a possible solution to the documented clinical site shortages and staff radiologic technologist limitations. The 2024 ARRT survey revealed that 67% of imaging facilities report staff shortages affecting clinical education, with 53% of programs losing clinical spots due to understaffing or competition. LXMO-certified students could perform routine imaging exams under indirect supervision, potentially alleviating staffing pressures and maintaining educational standards. Certified students working more autonomously could contribute to redistributing the limited clinical teaching resources, allowing staff technologists to focus more on novice students.

The workforce development implications of adding the LXMO exam and student certification may not directly improve national registry exam pass rates. However, it may still address workforce shortages by efficiently using clinical resources and potentially reducing program attrition by enhancing student confidence and engagement. The 2024 Consensus Committee emphasized that workforce challenges require "innovative solutions from the profession as a whole." (ASRT, 2024). LXMO certification represents an innovation that creates

a pathway for students to contribute to the clinical environment while completing their education. Overall, this approach may help address the 15% attrition rate reported by ASRT (2023) by providing students with earlier professional validation and practical experience, which could increase retention in the field.

The JRCERT requirements necessary to maintain programmatic accreditation place additional pressure on program faculty. The finding that LXMO-certified students achieved a 70.8% first-time pass rate on the national exam was concerning. This presents a dilemma for program directors considering the integration of LXMO certification, as it may offer benefits for clinical education and workforce development, but could potentially jeopardize accreditation status if implemented without careful planning and consideration.

As Brown (2023) discusses, programs must balance various approaches to improve registry exam pass rates, including promoting student self-efficacy through autonomy, competence, and relational support. Research findings suggest that programs implementing the LXMO certification should develop strategies to ensure students focus on comprehensive preparation for the national registry exam, rather than limiting their attention to specific competencies. This could include structured reviews of exam content for both exams, a targeted review, and additional education on the differences in content. Radiologic technology programs must ensure that clinical experiences encompass more than LXMO competencies. This broader approach would better prepare students for the comprehensive national registry exam and ultimately develop the skills needed for success as students and registered professionals.

**Recommendations for Future Research**

The LXMO certification can be used as more than a stand-alone certification. It can be used within radiologic technology programs or to build progression within the field of radiologic technology and advance professionalism nationally. The understanding of diversification and its potential impact has been demonstrated throughout the research. Additional research on creative ways to use the LXMO certification must be explored.

The study's findings primarily focused on determining whether the first-time pass rate of the national registry exam improved for LXMO-certified students compared to those who were not LXMO-certified. Based on the limited data results, this was not the case. As this exam has been limited to radiologic technology programs in Minnesota, it demonstrates the potential possibilities available to educators in Minnesota and nationwide. Prioritizing the use of this exam and embedding it methodologically into the program curriculum may benefit both students and educators. However, more data and analyses are needed to make that determination.

This study was limited by its small sample size of 24 students over a 25-year period (2000-2024), which restricted statistical power and generalizability. Future research should include substantially larger sample sizes to address this limitation, potentially by examining individual data from all 34 states that use the ARRT LXMO exam. This would provide a more robust statistical foundation for concluding the relationship between these exams.

The cross-sectional nature of this study prevented an examination of how the timing between exams affects outcomes—a critical factor mentioned in the discussion of the results. To overcome this limitation, future studies should employ longitudinal research designs that track

students from program entry through LXMO certification and national registry examination, documenting changes in student confidence, clinical independence, and skill development at multiple points. Such research would help determine the optimal timing between exams and provide insights into how LXMO certification affects education beyond simple exam performance metrics.

The unclear effect of self-selection bias, identified as a significant limitation in this study, could be addressed through controlled comparative studies that include matched groups of LXMO-certified and non-certified students with similar academic profile demographics. This approach would help isolate the specific impact of LXMO certification while accounting for other variables that might influence exam performance.

Another significant limitation is our inability to account for student characteristics and program factors. Future research should expand the variable analysis to include academic factors (such as program GPA or performance in key courses), clinical performance metrics, demographic characteristics, psychological factors (such as test anxiety or self-efficacy), and program characteristics. This varied approach would help identify which factors moderate or mediate the relationship between LXMO certification and performance on the registry exam.

Finally, this study's reliance on quantitative secondary data limited the understanding of students' experiences with both exams. To address this limitation, mixed-methods approaches incorporating qualitative elements such as interviews, focus groups, and case studies would provide valuable insights into how students perceive the relationship between these exams, their preparation strategies, and the psychological impact of LXMO certification on their approach to

the national registry exam—factors that cannot be captured through exam performance statistics alone.

## Summary

This study revealed that LXMO-certified students had a 70.8% first-time pass rate on the national registry exam, lower than the national average (85.2%) and the Minnesota average (83%). This failed to support the hypothesis that LXMO certification would improve registry exam performance. The CLT was used to explain these unexpected results, suggesting that limited-scope exam preparation may create mental frameworks too narrow for the comprehensive registry exam, possibly causing adverse knowledge transfer effects. Despite these findings, the study highlighted the potential benefits of LXMO certification, including increased clinical independence, reduced supervision requirements, and the potential to address workforce shortages. Potential opportunities exist with the LXMO certification; the challenge will be determining how to implement it successfully.

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# Appendix A IRB Approval

| | |
|---|---|
| FROM: | Winona State University IRB |
| PROJECT TITLE: | [2267678-1] What is the relationship between success on the Limited X-Ray Machine Operator exam and the first-attempt pass rate on the national registry exam among radiologic technology students in Minnesota? |
| SUBMISSION TYPE: | New Project |
| ACTION: | EXEMPT |
| REVIEW TYPE: | Exempt Review |

Thank you for submitting materials for the above project.

The IRB has determined this project is exempt according to 45 CFR 46.101(b).

You may begin your project.

While your project is exempt from further review, you must report to the IRB any significant modifications in your protocol, consent form, and/or data collection tool(s). All serious and unexpected events, non-compliance, or complaints must also be reported to this office.

For all reports, please use the report form in the IRBNet Forms and Templates Document Library and refer to the IRB Submission Guide document for instructions.

We will retain a copy of all your submitted materials and a copy of this correspondence within our records.

If you have any questions, please contact Tyler Treptow-Bowman. Please include your project title and reference number in all correspondence.

**Appendix B Minnesota Department of Health Tennessen Warning**

# Tennessen Warning

## Explanation of Rights

## For individuals applying for certification

The Commissioner of Health uses the information provided on an application to determine if you meet the requirements for certification. You are not required to provide any of the requested information. However, if the requested information is not provided, your application will be denied. Submitting false information will result in the denial of your application or suspending, revoking, or taking other disciplinary action against your certification.

Minnesota Statutes, section 270C.72, subdivision 4, requires you to submit your social security number to the Commissioner before a certification can be issued to you. The information submitted will not be disclosed outside the Minnesota Department of Health (MDH) during the application process. It may be disclosed to others, including the Attorney General's Office and persons contacted for purposes of verification or investigation, if required by law. Information on the application, including your social security number, will be provided to the Minnesota Department of Revenue (MDOR) at its request. If the matter of your certifications contested, the information submitted on the application may become public. When you become certified all information in the application becomes public, except your social security number, which remains private.