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Critical Thinking Skills and Medical Dosimetry Education

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CRITICAL THINKING SKILLS AND MEDICAL DOSIMETRY EDUCATION

BY

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Dedication

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CRITICAL THINKING SKILLS AND MEDICAL DOSIMETRY EDUCATION

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As a radiation oncology team member, medical dosimetrists use clinical knowledge and skills along with critical thinking to independently develop unique three dimensional radiation treatment plans for cancer patients that precisely target cancerous tumors, while sparing the normal surrounding tissues. Historically, medical dosimetrists entered the profession through several different pathways with the majority of practicing medical dosimetry professionals advancing from the ranks of radiation therapists (RTT). Beginning in 2017, the Medical Dosimetry Certification Board (MDBC) set the educational requirements to include a minimum of a Bachelor's degree and graduation from an accredited medical dosimetry educational program. Literature supports a positive relationship between critical thinking (CT) and education of health science professionals.

This is the first study to investigate if medical dosimetrists are well-developed critical thinkers, as measured by the Health Sciences Reasoning Test (HSRT). A cross-sectional, correlational study was used to gather quantitative data describing the CT skills of medical dosimetrists and to investigate whether CT skills of practicing professionals are stronger than

entry-level students. One hundred twenty-one subjects met the inclusion criteria of the study; 58 professionals and 63 students.

The results of this study revealed no significant difference between the groups for the total HSRT score, there was a significant difference between the groups in the inference sub-scale (p = <.001). The student group exhibited stronger inference skills compared to the professionals. Medical dosimetrists with a minimum of a Bachelor's degree had significantly stronger CT skills (p = < .001) than those with less education. Those who previously worked or trained as RTTs had significantly weaker CT skills (p = <.001) than those who did not and medical dosimetrists who attended an accredited medical dosimetry program had significantly stronger CT skills (p = .007) than those who attended a non-accredited program. There was also a significant negative correlation between CT skills and healthcare experience (r = -.23, p = 0.012, d = .27) that is worth further exploration.

This study provides meaningful support for the 2017 minimum educational standard for entry-level medical dosimetrists and provides for opportunities for further research with the medical dosimetry population.

Chapter I

Introduction

Background of the Problem.

Medical dosimetry is a relatively new health science profession in the specialty of radiation oncology, which is the medical specialty that uses radiation to treat cancer patients. According to the 2012 National Cancer Institute Surveillance, Epidemiology, and End Results (SEER) report, approximately 40% of men and women in the United States will be diagnosed with cancer during their lifetime and half of these patients will be treated with radiation therapy (Howlader, et al). In the course of their radiation treatment, the patient will meet several members of the radiation oncology team; a radiation oncologist, who is a physician specially trained in the treatment of cancer, a radiation oncology nurse, who is specially trained in the care of the radiation patient, and a radiation therapist (RTT), who delivers the daily treatments.

There are two members of the radiation team who work behind the scenes and seldom have contact with the radiation patient, a medical physicist and a medical dosimetrist. A medical physicist is an applied physicist who is master's or doctoral prepared and is concerned with the application of radiation in medicine. The medical physicist working in radiation oncology, assures the safe delivery of the radiation to the patient by calibrating the machines used to deliver the external radiation treatments,

called a linear accelerator, and performs periodic quality assurance tests to confirm that the linear accelerator is safe and complies with state and federal regulations. The medical physicist also supervises the treatment planning and reviews the radiation treatment plan for each patient. This individual verifies that the cancer patient receives the correct dose of radiation to the precise location prescribed by the radiation oncologist (AAPM, 2012). The other member of the team, who works closely with the medical physicist and radiation oncologist to create the radiation treatment plan, is the medical dosimetrist. The medical dosimetrist works under the supervision of a radiation oncologist and medical physicist to precisely design a unique radiation treatment plan for each individual patient. The medical dosimetrist designs the radiation treatment plan to maximize the cell kill of the cancerous tumor, while sparing the normal surrounding structures.

While medical dosimetrists work under the supervision of physicians and physicists, they perform much their day-to-day work independently. As the medical dosimetrist develops the radiation treatment plan, he/she will determine the energy, direction, and number of radiation beams used so that the radiation hits its target and avoids critical organs in the vicinity. All organs are sensitive to radiation, but some like the heart, lungs, and spinal cord are very sensitive and too much radiation may cause damage. Some damage is irreversible and once the radiation is delivered, the effects cannot be reversed (Bentzen, 2010).

The profession of medical dosimetry grew from a need to design radiation treatment plans in radiation oncology. In the early days of radiation oncology, the radiation treatment plan was simple, involving taking a few physical measurements of the patient and performing a straightforward calculation by hand. With the introduction of radiation treatment planning computers, sophisticated three-dimensional imaging modalities, and digital radiation treatment delivery machines, the radiation oncologist enlisted the assistance of a medical physicist and medical dosimetrist. The medical physicist is responsible for modeling the data collected from the linear accelerator in the radiation treatment-planning computer and confirming that the radiation treatment delivery parameters meet the intended prescription of the radiation oncologist (AAPM, 2012). The medical dosimetrist, trained by the medical physicist and radiation oncologist, operates the radiation treatment planning computer and develops complex and uniquely designed treatment plans for each individual patient (AAMD, 2011). The medical dosimetrist must decide which beam energy, what direction, and how many radiation beams are necessary to target the cancerous tumor, while avoiding the surrounding critical structures.

Radiation treatment planning is a very precise, highly technical process, giving rise to a plan that contains upwards of 10-12 different beam directions and over 100 different segments. The medical dosimetrist, who designs these radiation treatment plans, functions as an independent clinical

practitioner who uses their clinical knowledge and skills to make complex clinical decisions to develop a unique radiation treatment plan for each individual patient. About fifty percent of practicing medical dosimetrists completed at least a Bachelor's degree and fifty percent have less than a Bachelor's degree. Surprisingly, many of these critical healthcare practitioners possess no more than a high school education. Questions remain surrounding their education and clinical training, as well as the requirements for certification (Adams, 2010; Pusey et al, 2005).

In the health science professions, certification and licensure establish minimum competency for the entry level professional and in some professions, certification and/or licensure are mandatory for the independent practitioner (Giddens & Gloeckner, 2005; Pusey et al., 2005, AART, 2009, BOCATC, 2009). Few health science professions have no licensure or mandatory certification requirements and medical dosimetry is one of these professions (AAMD, 2011).

Like many health science professions, entry level into medical dosimetry evolved (AART, 2009, BOCATC, 2009, NCCPA). In the early years of the profession, the medical dosimetrist was a register radiation therapist (RTT), who was trained while working in a radiation oncology clinic under the supervision of a medical physicist and radiation oncologist (AAMD, 2011). The emphasis was on clinical knowledge and skills and not focused on the individual's formal education. The majority of medical dosimetrists

were trained as radiation therapists in a post high school certificate program and medical dosimetry was considered an advance practice of radiation therapy technology.

As the numbers of medical dosimetrists increased, the American Association of Medical Dosimetrists was chartered in 1975 to meet the professional, educational, and scientific needs of the individuals working as medical dosimetrists. Following a long-standing tradition in medical professions, voluntary certification in the specialty of medical dosimetry followed with 136 candidates taking the inaugural Medical Dosimetry Certification Board examination (MDCB) in 1986. No minimum educational background was required for the examination, although all 136 candidates satisfied the original eligibility requirements of six years clinical medical dosimetry on-the-job-training experience (OJT). (Pusey, et al., 2005).

Certification remains voluntary, but the eligibility requirements of the MDCB examination evolved. Now, the eligibility requirements for the MDCB examination include both an educational component and a clinical training component. Today medical dosimetry candidates may become eligible to sit for the examination through three different pathways (MDCB, 2012).

Route one requires that the candidate graduate from a Joint Review Committee on Education in Radiologic Technology (JRCERT) accredited medical dosimetry educational program. JRCERT is the only agency designated by the federal government to accredit radiologic technology
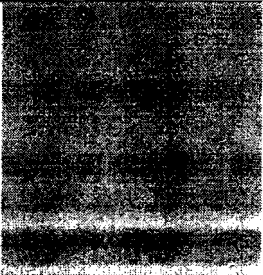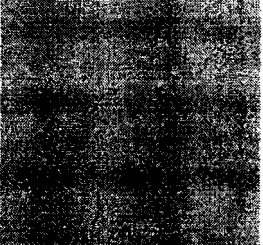
educational programs and programs must meet a 12-month minimum to adhere to the standards set by JRCERT for accreditation.

Route two requires that the candidate possess a minimum of a Bachelor's of Science degree (BS) or active certification in radiation therapy technology (RTT) and complete 24 months clinical medical dosimetry training. Route three requires that the candidate possess a Bachelor's of Arts degree (BA) or Associate's degree in science (AS) and complete 36 months medical dosimetry clinical training. Beginning with the 2013 examination, only candidates with a minimum of a BS or RTT and 24 months clinical medical dosimetry training will be accepted through this alternate route and unless RTT candidates posses a Bachelor's degree, they will no longer be eligible in 2015. In 2017, the requirements are restricted to only one route for all candidates; a minimum of a B.A. or B.S. and graduate of a JRCERT accredited medical dosimetry program (AAMD, 2009). (Table 1)

Graduation from accredited educational programs and attaining a higher education are indicators of success in various health science professions (Starkey & Henderson, 1995, Williams & Hadfield, 2003, Raymond & Washington, 2002, Asprey, Dehn, Kreiter, 2004). Accredited health science professional educational programs must meet standards specific to the expertise necessary for entry-level professionals (AART, 2009, BOCATC, 2009, AAMD, 2011). Common standards include teaching the content specific clinical knowledge and skills to pass the certification and/or

Table 1

Eligibility routes for Medical Dosimetry Certification by MDCB.

Year	Route1	Route 2	Route 3
2012	Graduate from a JRCERT program of at least 12 months	RTT -OR- BS in related science AND 24 months clinical Med Dos experience AND 12 approved CE credits	AAS or AS or BA AND 36 months clinical Med Dos experience AND 12 approved CE credits
2013	Graduate from a JRCERT program of at least 12 months	RTT -OR- BS in related science AND 36 months clinical Med Dos experience AND 24 approved CE credits	
2015	Graduate from a JRCERT program of at least 12 months	BS in related science AND 36 months clinical Med Dos experience AND 24 approved CE credits	
2017	BA or BS AND Graduate from a JRCERT program of at least 12 months		

licensing examination, reflective of an entry-level professional, and developing critical thinking skills necessary to practice as an independent health science practitioner.

Various definitions for critical thinking are found in literature (Dewey, 1933, APA, 1990, Watson & Glase, 1980, Ennis, 1993, Facione, 1990, Brookfield, 1987, Paul, 2005). Health science literature supports the fundamental link between critical thinking and clinical reasoning (Mattingly, 1991, Finn, 2011, Kamhi, 2011, Giddens & Gloeckner, 2005, Bowles, 2000, Williams, et al., 2003, Vendrely, 2005, Rogal & Young, 2008). Lewis, Arthur, & Smith (1993) describe critical thinking as a high order thinking process, where individuals interrelate new information and knowledge stored in memory to answer a perplexing question or achieve a purpose. In the health sciences, Mattingly (1991) relates critical thinking to problem solving. Various authors present evidence that critical thinking is developed in higher education and through active learning processes. Kamhi (2011) states that one's belief system and critical thinking influence clinical decision-making.

Some evidence exists to support the relationship between education and critical thinking skills of health science professionals (Raymond & Washington, 2002, Asprey, Dehn, Kreiter, 2004). Literature also supports the relationship between critical thinking skills and success on certification and licensing examinations (Williams & Hadfield, 2003).

Need for the Study.

According to the American Cancer Society, the number of new cancer cases is increasing by about 2% per year and about 50% of cancer patient are treated with radiation (ACS, 2012). By 2020, the American Society of Clinical Oncology predicts that due to an increase in aging, growth of the population, and improvements in cancer survival rates, the demand for qualified radiation specialists will increase (ASCO, 2012). One such health science profession that will experience this increased need is medical dosimetry. Even without mandatory certification or licensure, healthcare institutions demand that medical dosimetrists validate their of level competency by passing the MDCB examination.

The eligibility requirements for the MDCB are evolving and in 2017, a Bachelor's degree and graduation from an accredited medical dosimetry program will be the only route toward certification (MDCB, 2012). In other health science professions, evidence exists that students who graduate from an accredited program and students who possesses a degree have higher critical thinking skills and are more successful in passing the certification and/or licensing examination (Starkey & Henderson, 1995, Williams & Hadfield, 2003, Raymond & Washington, 2002, Asprey, Dehn, Kreiter, 2004). Currently, there is no evidence concerning the critical thinking skills of medical dosimetrists.

Radiation OOcologists and medical physicists technically supervise medical dosimetrists, even though much of their daily responsibilities include independently performing highly technical and very precise tasks. Each computer modeled treatment plan is designed for an individual patient to treat their unique disease. During the process the medical dosimetrist analyzes the situation presented to him/her while developing the optimal plan for the unique patient. The medical dosimetrist makes clinical judgments following scientific principles and evidence-based guidelines. They evaluate the integrity of the final product and decide which plans they will present to the physician for approval. Since about seventy percent of practicing medical dosimetrists work as solo practitioners in small freestanding clinics or community centers, they are expected to do much of their work independently and utilize critical thinking skills.

For purposes of this study, the operational definition of critical thinking is high order thinking based in active evaluation, interpretation, analysis, and assessment of a unique patient in a unique situation demonstrated in problem solving using evidence-based decisions and reflective judgment.

Purpose of the Study.

The primary purpose of the study is to explore the critical thinking skills of medical dosimetrists, as measured by the Health Sciences Reasoning Test (HSRT).

A secondary purpose of the study is to investigate whether critical thinking skills of medical dosimetrists increase over the learning spectrum; from entry-level student to practicing professional. Post-hoc analyses are planned for age, gender, education, prior healthcare experience, prior medical dosimetry experience, and RTT status.

Research Questions.

For the purpose of this study, the primary research questions were:

- Do medical dosimetry professionals who are currently practicing medical dosimetry demonstrate strong critical thinking skills as measured by the HSRT?

- Do students at the beginning of a formal medical dosimetry educational program (entry-level students) demonstrate moderate critical thinking skills as measured by the Health Sciences Reasoning Test (HSRT) (Insight, 2010)?

- Will practicing medical dosimetry professionals demonstrate stronger critical thinking skills than entry-level medical dosimetry students, as measured by the HSRT?

Research Hypotheses.

The research questions provided a basis for developing the

hypotheses for this study are:

- H1: medical dosimetry professionals who are currently practicing

  medical dosimetry will demonstrate strong CT skills, as measured by

  the HSRT.

- H2: Entry-level students enrolled into a medical dosimetry educational

  program will demonstrate moderate critical thinking skills, as measured

  by the HSRT.

- H3: Medical dosimetry professionals will demonstrate stronger CT

  skills then entry-level students enrolled into a medical dosimetry

  educational program, as measured by the HSRT.

Chapter II

Literature Review

Medical Dosimetry.

Medical dosimetry is a health science profession in radiation oncology recognized by the American Medical Association. The profession evolved from the need to assist the medical physicist and radiation oncologist to provide a high level of precision to radiation dose planning and delivery in the treatment of cancer patients (AAMD, 2008a). In 1975, the growing number of medical dosimetrists formed the American Association of Medical Dosimetrists (AAMD) as an international society to promote and support the medical dosimetry profession through education, professional interaction, and representation within healthcare (Pusey, et al., 2005).

Historically, medical dosimetrists began their careers as registered radiation therapists (RTT) and were trained in the radiation oncology clinic to function as medical dosimetrists by certified medical physicists and radiation oncologists. The results of the 2012 workforce survey revealed that the majority of practicing medical dosimetrists previously practiced as radiation therapists (AAMD, 2012). As with other health science professions, the AAMD leadership decided that some measure of competency should be established in the practice of medical dosimetry (Pusey, et al., 2005). In 1988, the Medical Dosimetry Certification Board (MDCB) was incorporated and charged with the certification of medical dosimetrists. The mission of the

MDCB is to elevate the profession, determine certification eligibility, conduct examinations, grant certificates to successful candidates, and offer a registry service to certified medical dosimetrists (CMDs) (MDCB, 2007).

Eligibility requirements for the MDCB examination evolved along with the profession. Table 1 lists the eligibility requirements and future modifications (MDCB, 2009). The inaugural examination served as a grandfather clause, allowing practicing medical dosimetrists with a minimum of 6 years experience opportunity to become certified. There was no minimum educational requirement. This route of eligibility was subsequently eliminated and since 2004 all of the requirements include both educational and supervised clinical medical dosimetry training components. Keeping with tradition, though, RTTs are able to become eligible for the examination without additional education, but they must complete clinical medical dosimetry training and continuing education credits. This route of eligibility will remain until 2017 (Pusey, et al., 2005, MDCB, 2009).

Certification is widely used in health science professions to set standards for qualified individuals to practice within the profession and to protect and improve the health and safety of individuals who are the recipient of the services. Professional certification examinations elevate professions and determine minimum competency level for clinicians practicing in those professions. (Giddens & Gloeckner, 2005, Pusey et al., 2005).

Certification and licensure requirements are not uniform through the

United States for medical dosimetrists. In an attempt to standardize credentialing of healthcare individuals who work in medical imaging and radiation therapy, including medical dosimetrists, there is pending federal legislation that addresses minimum education and certification requirements of all radiologic healthcare professionals. The CARE Bill (Consistency, Accuracy, Responsibility, and Excellence in Medical Imaging and Radiation Therapy bill, S. 3338), was again introduced in the United States Senate in June, 2012 (ASRT, 2012). The legislation will require states to set a minimum level of education, knowledge and skill for radiologic personnel to ensure quality of care and protect patients (AAMD, 2008c). In 2012, the bill gained momentum for legislative support and currently has 125 bipartisan cosponsors. The bill will also require medical professionals in radiology and radiation oncology, including medical dosimetrists, to become certified, ensuring that patients undergoing radiologic procedures have the same assurance of quality as provided in the Mammography Quality Standards Reauthorization Act of 1998 and 2004 (MQSA) (ASRT, 2010). The CARE Bill is endorsed by many professional organizations, including the AAMD, American Association of Physicists in Medicine (AAPM), American Society of Therapeutic Radiation Oncologists (ASTRO) and American College of Radiology (ACR) (AAMD, 2008c). It is likely that once the bill passes, individual state licensure and health care reimbursement standards will follow (Adams, 2010; Pusey et al., 2005).

Although medical dosimetry certification is not required by law, it is endorsed by program accreditation organizations; ASTRO, ACR and the American College of Radiation Oncology (ACRO). These organizations have active programs to accredit radiology and radiation oncology practices and outline minimum standards for personnel within a radiation oncology practice in their standards of practice. Their accreditation program requirements state that MDCB certification is recommended for all medical dosimetrists working clinically in radiation oncology (ACR, 2007, ACRO, 2008).

Radiologic professional and accrediting organizations continually emphasize the need for board certification in medical dosimetry. As reported in the 2012 AAMD salary survey, there are over 2500 members in the AAMD and over 90% of them are certified by the MDCB and less than 10% are not certified (AAMD, 2012). According to the AAMD, it is difficult to estimate the number of non-certified professionals practicing medical dosimetry (AAMD, 2008d). Pusey, et al (2005) estimated that in 2004 half of all practicing medical dosimetrists were not certified and that passing the MDCB examination is difficult for medical dosimetrists who did not attend a formal training program.

Prior to 2008, graduates of any formal medical dosimetry program could apply for the MDCB examination, but a major change in the MDCB examination eligibility requirements occurred with the 2010 examination. Beginning with the 2008 examination, the MDCB Board of Directors specified

that candidates who apply through route 1 must be graduates of a Joint Review Committee on Education in Radiologic Technology (JRCERT) medical dosimetry program and non-accredited program graduates may only apply through route 2 or 3, thus endorsing the importance of formal, accredited allied health education (MDCB, 2009b).

In 2017, an additional educational requirement will be added and all candidates must have a minimum of a Bachelor's degree, in addition to graduating from a JRCERT accredited medical dosimetry program. The MDCB examination is not meant to be an entry-level examination, but rather designed as a high-level examination for skilled, trained and educated medical dosimetrists (Adams, 2010).

As of 2013, there are 17 JRCERT accredited medical dosimetry programs in the United States with a total capacity for 166 students (JRCERT, 2013). JRCERT is the only agency recognized by the US Department of Education designated to accredit educational programs in the radiologic professions and is responsible for accrediting programs in diagnostic radiology, radiation therapy, magnetic resonance, as well as medical dosimetry. The Board of Directors of JRCERT consists of radiologic educators, experienced practitioners and recognized leaders in the field of radiologic specialties. While JRCERT does not prescribe a specific approach to program assessment, the Board of Directors, with input from relevant communities, develops a set of accreditation standards that are reviewed

every five years.

In 2010, JRCERT adopted six standards for medical dosimetry programs, directing program assessment and student outcomes and including articulation of the program's mission, goals, outcomes and effectiveness, description of the program's organization and administration, and a statement of the curriculum, program resources and services available to the students. The applicant program provides an application and self-study report evaluating the program's ability to accomplish its purposes and develops a plan for future program improvement. After a successful site visit, where a member of the JRCERT site review committee interviews students, teachers, and administrators, the program receives JRCERT accreditation for a maximum of eight years (JRCERT, 2013).

JRCERT accreditation ensures that programs provide consistent minimum education, providing students with the knowledge, skills, and values to competently perform their professional responsibilities. All graduates of JRCERT accredited medical dosimetry programs are eligible to take the MDCB examination (MDCB, 2009b).

The MDCB certification examination is currently a computer-based examination offered several times each year at several sites throughout the United States and abroad. In recent years, about 400 candidates are approved each year to take the examination and the pass rate ranges from 50-65% (MDCB, 2013). The MDCB examination pass rate falls in the

"middle" of professional examination pass rates, with Certified Public Accountant Examination (CPA) pass rates around 30% and American Registry of Radiologic Technologists (ARRT) around 90% (Adams, 2010).

The examination is designed as a multiple choice, standardized test with questions submitted by experts in the field of radiation oncology and subsequently reviewed and refined by the MDCB Test Development Committee. The examination tests both the knowledge and clinical competency of the candidate, but the question remains of the efficacy of standardized tests as a predictor of knowledge, critical thinking skills, and clinical competency (Adams, 2010; MDCB, 2009b).

Professional Certification and Licensure Examinations.

Educational institutions use results of multiple-choice, standardized tests as predictors of success in many avenues of education. Several authors challenged this routine practice. Linn (2001) discussed the controversies surrounding the use of standardized tests for both grade-to-grade promotion and college admissions. Despite these controversies, it is common practice that institutions of higher learning set standards for admission based upon standardized, multiple-choice tests.

Two high profile tests used by institutions as a basis for admission decisions are the Scholastic Assessment Test (SAT) and the American College Test (ACT). In 2002, Geiser and Studley published a study on the predictive validity of SAT I and SAT II tests at the University of California. The

SAT I, now known as the SAT Reasoning Test, tests students' knowledge of three subjects; mathematics, critical reading, and writing. It is intended to assess students' aptitude for future learning based upon skills that the students learned in high school. The test utilizes several different types of questions, including multiple-choice questions (MCQ), student-produced responses, and a student-produced essay. The SAT II, now known as Subject Test, uses only MCQs to measure the students' knowledge and skills in a particular subject. The Geiser and Studley (2002) study retrospectively reviewed over 75,000 student records and found that SAT II scores were more predictive of freshman grades than SAT I scores. If college success is measured by freshman's grade point average, than the SAT II (Subject Tests) showed an advantage over the SAT I (Reasoning Test) in predicting college success. The literature supports the use of standardized tests useful to measure success when the test measures knowledge and skills in particular subject areas, rather than reasoning.

In the health sciences, certification examinations need to assess not only knowledge, but also clinical judgment and skills to confirm minimum competency (Starkey & Henderson, 1995, Raymond & Washington, 2002, ARRT, 2009, MDCB, 2009, BOCATC, 2009). MCQs, if written appropriately, may address not only knowledge, but also critical thinking skills necessary to demonstrate clinical application of the knowledge. Some professions add simulation and practical sections into a certification exam to complement the

MCQs (BOC, 2009). Simulation questions are designed to test critical thinking and clinical skills and transcend the first levels of Bloom's taxonomy for cognitive thinking. Questions that instruct the reader to apply, analyze, synthesize and evaluate are questions considered suitable for evaluating critical thinking and clinical skills. To guide item writers for certification examinations in the radiologic sciences, the American Registry of Radiologic Technologists (ARRT) provides a question-writing manual. The manual emphasizes writing practice-based questions using higher-level Bloom's taxonomy structure. These questions aim to assess cognitive skills that underlie the basic clinical knowledge (ARRT, 2003).

Professional Training and Education.

Medical dosimetrists use their broad knowledge, professional judgment, and critical thinking skills to make appropriate clinical decision. Working under the guidance of radiation oncologists and medical physicists, medical dosimetrists design patient specific radiation treatment plans. During this treatment planning process, medical dosimetrists use their knowledge of the physical treatment machines and the clinical techniques utilized in radiation oncology to construct a plan that directs the radiation beams toward the treatment volume and avoids the critical structures. Medical dosimetrists perform complex tasks and critically synthesize their knowledge of mathematics, anatomy, physiology, oncology, and radiation physics. They undertake many responsibilities within the radiation oncology clinic and very

often are the liaison between the medical physicist and the rest of the technical staff (AAMD, 2008a; Pusey et al., 2005).

Formal health science education and training are the basis for developing cognitive skills and clinical knowledge that are needed clinical practice (Asprey, et al., 2004, Williams & Hadfield, 2003, Vogel, et al., 2009, Sayre-Stanhope, 2005, Donini-Lenhoff, 2008). Today, practicing health professionals encounter increased complexity of techniques using highly sophisticated equipment and must apply their clinical knowledge while strategizing in the clinical setting (Donini-Lenhoff, 2008, Vogel, et al., 2009, Sayre-Stanhope, 2005). The goal of health science educational programs, including medical dosimetry, is to develop health care professionals, who have the knowledge and clinical skills, but also are competently skilled in higher-level critical thinking and can successfully pass the professional certification examination (Vendrely, 2005; Lederer, 2007).

Critical Thinking and Clinical Reasoning.

In 1990, the Committee on Pre-College Philosophy on the American Philosophical Association convened a panel of experts to develop a consensus of the role of critical thinking in educational assessment and instruction. The research resulted in recommendations addressing the development and assessment of critical thinking skills and it became the foundation for critical thinking in higher education. The panel of experts identified critical thinking as an essential tool of inquiry using purposeful, self-

regulatory judgment. They listed six core cognitive skills that define good critical thinking skills; interpretation, analysis, evaluation, inference, explanation, and self-regulation. (Facione, 1990).

Interpretation skills are used to logically understand or find the meaning of a situation, belief, or judgment. Interpretation is used in language, art, science, mathematics, philosophy, and law. Analysis is the systematic process of identifying the actual or intended relationships by breaking down the essential components of the situation, opinion, or judgment. Evaluation is the critical assessment of a statement or claim to determine its credibility or logical strength. Science and mathematics rely heavily on both analysis and evaluation skills. Inference skills are used to draw conclusions from evidence and reason. When evidence is limited or absent, inference skills are used to hypothesize a decision based on statements, beliefs, and opinions. Explanation is the systematic description of one's decision stating the facts, clarifying the causes and concepts, and justifying the argument with reason. Self-regulation is the ability to self-consciously question, challenge, validate, and correct one's results by using the other skills of analysis and evaluation.

According to the APA consensus report, the ideal critical thinker is inquisitive, well-informed, open minded, flexible, honest in facing personal biases, prudent in making judgments, orderly, willing to reconsider, diligent in seeking relevant information, focused in inquiry, and persistent in seeking results (Facione, 1990).

Definitions of a critical thinker by many experts are found in literature. Dewey (1933) describes a critical thinking as one who integrates new problems within one's experiential framework. Several authors describe critical thinking as reflective thinking (Ennis, 1962, 1985, 1993, Broomfield, 1987). Watson and Glaser (1980) designate skills, knowledge, and attitudes as essential while making inferences and generalizations. Paul (1993, 2005) describes critical thinking as an interrelated process requiring reflective, purposeful and systematic thinking.

Critical thinking was also described by education and clinical specialists (Mattingly, 1991, King, 1993, 1995, Lewis & Smith, 1993, Lemming, 1998, Finn, 2001, Kamhi, 2011). Mattingly (1991), an occupational therapist, describes critical thinking as solving a puzzle. She elaborates that clinicians must deliberate about an appropriate action in a particular case, with an individual patient, at a specific point in time.

Educators introduced teaching techniques to enhance critical thinking skills. King (1993, 1995) introduced that modeling, active learning, and asking thought provoking questions are central to critical thinking. Lewis & Smith (1993) defined critical thinking as high order thinking when a person takes new information stored in memory and interrelates or rearranges and extends this information to achieve a purpose or find possible answers to perplexing situation.

As a clinician, Lemming (1998) described critical thinking as reflective

judgment grounded in relevant data. Finn (2001), a speech pathologist, defines critical thinking as applied rationality, when the individual has a set of learned skills and apply these skills in their everyday professional lives. Kamhi (2011), also a speech pathologist, supports the use of evidence-based models to provide principles and guidelines for clinical practice, but emphasizes that clinical decisions are also influenced by the practitioner's belief systems and critical thinking.

Measuring Critical Thinking Skills.

Simpson and Courtney (2002) completed a comprehensive literature review of critical thinking in nursing education which reported that critical thinking skills are necessary for nurses working in the clinical setting and that nursing educational programs focus on developing the students' critical thinking abilities using instructional strategies, such as problem based learning (PBL). Many of the studies used the California Critical Thinking Skills Test (CCTST) as an instrument to measure critical thinking skills of healthcare professionals (Bowles, 2000; Colt, 2007; Giddens & Gloeckner, 2005; Rogal & Young, 2008, Vendrely, 2005; Williams et al., 2003).

Giddens and Gloeckner (2005) observed that graduate nursing students from one university-based nursing program who passed the National Council Licensure Examination for Registered Nurses (NCLEX-RN) had significantly higher total critical thinking scores (p = 0.003) on the CCTST than those students who failed the NCLEX-RN. Vendrely (2007) found significant

relationships (r = 0.35; p = 0.02) between critical thinking skills as measured on the CCTST and success on the National Physical Therapy Examination (NPTE). Williams et al. (2003) used a mixed methods design to explore the predictive validity of critical thinking skill for candidates of seven baccalaureate-level dental hygiene program students. A panel of experts convened to define, develop and refine criterion measures and then these measures, The CCTST and predictor variable were collected from a sample of 207 first-year dental hygiene students. The authors demonstrated through multiple regression analysis that CCTST scores significantly explained a variance in some of the predictive variables; initial clinical reasoning scores (p < .001), acquired knowledge (p = .001), and faculty ratings (p < .001).

Simpson and Courtney (2002) identified several authors who challenged the use of the CCTST to effectively evaluate critical thinking skills of nurses as health professionals and proposed the development of another tool specifically targeting healthcare professionals. Recently, Insight Assessment, a division of California Academic Press adapted the CCTST for health professionals. The Health Sciences Reasoning Test (HSRT) uses 33 MCQs taken from the CCTST item pool, but framed in health science and professional practice contexts. Insight Assessment reports an overall internal consistency score of 0.81 (Kuder-Richardson) for the HSRT and validation studies are ongoing (Insight Assessment, 2010). The HSRT may be useful to evaluate critical thinking skills of health science professionals and possibly

serve as a predictor for success on certification examinations.

Health Science Professional Competency.

The goal of health science professional certification examinations is to test for minimum clinical competency. Incorporating critical thinking evaluation within certification examinations is essential. The National Athletic Trainers' Association Board of Certification Examination (NATABOC) developed an exam designed to test critical thinking in clinical scenarios. It contains three sections: written, written simulation and oral/practical (Starkey & Henderson, 1995). The written section includes multiple-choice questions and stand-alone alternative items. The test includes questions that require multiple answers and drag and drop questions that require the respondent to click on an image or item to select the answer. The written simulation section consists of five focused test items. In each test item, the respondent is presented with a clinical scenario and answers critical questions related to that scenario. While the MCQs are designed to test knowledge, the alternative items and written simulation scenarios are aimed at evaluating critical thinking and clinical application of the knowledge (BOCATC, 2009). Each health sciences profession is challenged to incorporate critical thinking questions in their particular certification examination.

Standards for accreditation of health sciences educational programs, routes of eligibility for certification, and certification examinations are the responsibility of the individual professional organization and vary widely

between allied health specialties. Many specialties have several routes of eligibility that require an academic route and/or internship and/or practical on-the-job training route (ARRT, 2009, BOCATC, 2009, MDCB, 2009).

While graduation from an accredited program does not guarantee success on passing professional examinations, research in several health science professional fields shows that attendance in formalized educational programs increases the likelihood of passing certification examinations (Harrelson et al., 1997; Starkey & Henderson, 1995; Vendrely, 2007; Yin & Burger, 2003). Selected variables that may predict success of passing on the first attempt of the NATABOC were investigated retrospectively. Harrelson, et al. (1997) reviewed student records of subjects that were enrolled in one undergraduate program and followed up with a telephone survey to supplement the historical data. The authors concluded that academic variables were the strongest predictors of success on the examination. One of the academic variables was the number of semesters of university enrollment.

Starkey and Henderson (1995) concluded that candidates who completed an accredited curriculum had significantly higher pass rates than those who met eligibility requirements by only completing an internship program. Williams & Hadfield (2003) concluded that the highest pass rate for first-time takers were graduates of formal athletic training programs that strongly emphasized clinical competencies, thus enhancing the students'

abilities to think critically and apply knowledge in a clinical scenario.

Vendrely (2007) concluded that using a two-tailed Pearson product moment, there was a positive correlation ($r = 0.31$; $p = 0.05$) between the CCTST and the scores on the National Physical Therapy Examination (NPTE) and a positive correlation ($r = 0.33$; $p = 0.04$) between grade point average (GPA) and the scores on the NPTE. Although the study was limited in size and subjects were from only one physical therapy program, the research suggests that health science education is complex and more research is necessary to investigate how best to develop clinical knowledge and skills and critical thinking skills in health science students.

In the radiologic sciences, Raymond and Washington (2002) studied the relationship between educational preparation and performance on the American Registry of Radiologic Technologists (ARRT) examination in radiation therapy. The study concluded that only some of the mean test scores in three educational categories, Bachelor's degree, Associate's degree, and certificate programs were statistically significant, but in all categories the differences were small. On the total test, candidates with Associate's degrees scored slightly lower, but not statistically significant, ($p = 0.10$) than Bachelor's degree candidates. Only on the treatment planning section did candidates with Associate's degrees score lower ($p = 0.01$) than either certificate or candidates with Bachelor's degrees. In the category of critical thinking, candidates with Associate's degrees scored lower ($p < 0.01$)

than either candidates with Bachelor's degrees or certificates. There were several limitations to the study, including that it was a retrospective study with twenty five percent of the sample eliminated due to incomplete or ambiguous information about educational programs. The study did, however, suggest that while degree programs might not result in higher test scores for an entry-level test, they might lead to better performance on advanced practice tests.

The current research illustrates a gap in the literature linking critical thinking skills, education, and pass rate of certification or licensure examinations in health science professions. This gap strongly exists with medical dosimetrists, as the entry-level requirements are very diverse. Ninety percent of CMDs have some type of post high school education, but just slightly over 50% hold a minimum of a Bachelor's degree and only 20% completed a formal medical dosimetry educational program (AAMD, 2008d). Ninety percent of practicing medical dosimetrists is certified and 81% also hold a certification as a radiation therapist. Surprisingly, the pass rate on the MDCB has been around 57% over the past 5 years (Adams, 2010; AAMD, 2008d).

Adult Learning.

The 2008 AAMD salary survey indicated that the majority of CMDs working in the field are between the ages of 40 and 49 with only eleven percent of respondents under the age of 35 (AAMD, 2008d). As medical dosimetry professionals age, the demand for additional certified medical

dosimetrists entering the field will surely increase. Based upon the current and future eligibility requirements for MDCB certification, future of medical dosimetry candidates will be students who have pursued some formal education beyond high school. They will either possess a Bachelor's degree or have graduated from a formal radiation therapy or medical dosimetry program. All of these candidates are considered adult learners.

Learning as an adult is uniquely different from learning as a child or young adult. The theoretical framework of adult learning, andragogy, was pioneered in Europe in the 1960's and the concept introduced in the US by Dr. Malcolm Knowles (Knowles, 1968). A core assumption in the theory of adult learning is that adults are self-directed learners and throughout their life, adults experience the need to learn information they need for immediate application (Knowles, 1968). Adults tend to set clear, specific goals for their education and are motivated to succeed because of their life obligations. In the 1970's, several authors added a new dimension to andragogy in higher education (Cross, 1976). Stark and Lattuca (1997) reported statistics from the National Center for Education on the education of the adult population. "A higher percentage of our adult population attends college than in any other nation in the world, and adult enrollment is still rising. Approximately 56% of all college enrollees are over 24 years old; many attend on a part-time basis and live with their own nuclear families or parental families instead of same-age roommates." (p. 61)

As a result of the influx of adult learners in higher education, the 1960's brought about the development of the nontraditional colleges, colleges that awarded credit for experience (Stark & Lattuca, p. 337). In the 1970's, distance learning led to the concept of "colleges without walls". Both of these innovated changes in higher education are attractive to the adult student, who has personal obligations and is working full or part time.

Of the seventeen JRCERT accredited medical dosimetry programs, only two programs offer distance learning and only one offers a part-time alternative. The remaining programs are on-site, full time programs (JRCERT, 2013). Since individuals pursuing certification in medical dosimetry are adults, with the majority practicing as certified radiation therapists, it might suggest that formal educational programs in medical dosimetry accommodate adult learners applying the rich research in andragogy. To foster success, accredited medical dosimetry educational programs not only need to promote knowledge and ensure clinical competency, but also warrants attention to the learning needs of the adult student population, with increased opportunities to incorporate distance learning and part-time programs. Since medical dosimetry is considered an advanced practice profession in radiation oncology, alternative-learning programs may offer radiation therapists an opportunity to continue working while pursuing studies in medial dosimetry.

Summary.

Medical dosimetry is a health science profession in radiation oncology. The education, training and certification of medical dosimetrists are evolving towards minimum educational requirements (AAMD, 2010). Beginning is 2017, eligibility for the MDCB examination will be open to candidates who graduated from a JRCERT accredited educational program and possess a minimum of a bachelor degree. The MDCB examination is the current measure of knowledge and clinical skill for medical dosimetrists seeking certification. While certification of medical dosimetrists is voluntary, it is anticipated that in the future, certification will become mandatory if and when the CARE Bill succeeds in Congress (Adams, 2010; Pusey, 2005).

A gap in the literature provides an opportunity to investigate the relationship between the educational background of the candidate, the type of program that the candidate attends, and critical thinking skills of medical dosimetrists.

While graduating from an accredited program does not guarantee success, research shows that health science students who completed accredited educational programs had higher pass rates on national certification examinations. A retrospective study by Starkey and Henderson (1995) reported that athletic training curriculum candidates had significantly higher scores than internship candidates. Dickinson, Hostler, Platt & Wang (2006) reported that students who attended an accredited paramedic program

were more likely to pass the national certifying examination. Pusey, et al. (2005) and Adams (2010) state that pass rates for graduates of formal medical dosimetry programs have higher pass rates than those who do not.

The traditional design of certification exams, including the MDCB, includes a majority of standardized, MCQs. Literature shows that only appropriately written examination items test for critical thinking skills and clinical competency. An analysis of the types of questions used on the MDCB examination may provide constructive information to item writers and encourage the use of alternative items and written simulation test items, which have proven to be better in evaluating critical thinking and clinical application of knowledge, and predicting early professional success (Williams & Hadfield, 2003, BOCATC, 2009). Accredited health science programs incorporate critical thinking into the curriculum, which is essential in developing competent clinicians and successful in passing certification examinations (Vendrely, 2007; Giddens & Gloeckner, 2005).

While some health science professions have studied pass rates on certification examinations based upon the candidates' education, training, and route of eligibility, there is a gap in the literature that evaluates the candidate's route of eligibility and success on the MDCB examination. Like other health science professionals, medical dosimetrists are recognized as autonomous practitioners once they have successfully passed the certification examination. Within the theoretical frameworks of critical thinking and

andragogy, this research proposes to investigate if the successful medical dosimetry candidate is also a well-developed critical thinker and is related to the route of eligibility of the candidate.

This information may prove invaluable to the Boards of Directors of the MDCB and JRCERT, medical dosimetry program directors, and potential medical dosimetry candidates. The MDCB will benefit from such research, providing scientific evidence that questions that test for critical thinking and clinical competency should be incorporated into the exam. The Board of Directors of JRCERT can utilize the research to assess the accreditation standards for medical dosimetry programs, in particular critical thinking skills. Medical dosimetry program directors will benefit from the research as they improve the curriculum and adapt programs to accommodate working, adult learners. Finally, potential medical dosimetry students will be better prepared to enter the profession of medical dosimetry, which will lead to safer radiation treatment delivery to the cancer patient. The outcome of a correlative study will guide potential students in their decision on their path into the profession and potentially indicate early professional success as a CMD.

Medical dosimetry is a highly technical, advanced radiologic profession, requiring the certified dosimetrist to apply critical thinking skills to make clinical decisions. The problem with the current certification process is twofold. First, there are three very distinctive routes of eligibility with varying educational and clinical components. Only in the first route do candidates

graduate from a formalized education and training program in medical dosimetry and medical dosimetry students have limited choices for accredited programs. Secondly, there is a need for more certified medical dosimetrists, but the pass rate on the MDCB examination has historically been between 50 - 60% (Adams, 2010). The implication of the low pass rate is that the exam is not an entry-level examination, but rather a complex examination designed for the highly skilled, trained, and educated medical dosimetrist (Adams, 2010; Pusey, 2005). A question remains if the test items on the MDCB test truly test a high level of clinical knowledge, clinical skills, and critical judgment. Another question should explore the critical thinking skill level of certified medical dosimetrists. Certification assumes that the candidate that passes the MDCB is an individual with a broad base of theoretical knowledge and a high level of clinical competence and may practice as an integral part of the technical team in radiation oncology.

Chapter III

Methods

Design.

Portney and Watkins (2009) illustrates clinical research as a continuum and reflective of the type of question being asked. Research methods may be divided into three classifications; descriptive, exploratory, or experimental. This study is designed as a descriptive and cross-sectional, correlational exploratory study. Quantitative analysis was used to (1) explore critical thinking skills of medical dosimetry professionals who are currently practicing medical dosimetry, as measured on the Health Sciences Reasoning Test (HSRT), (2) explore critical thinking skills of entry-level medical dosimetry students, who are enrolled in a formal medical dosimetry educational program, as measured by the HSRT, and (3) determine if practicing medical dosimetry professionals have stronger critical thinking skills than entry-level medical dosimetry students.

Variables.

The independent variable is the point along the learning spectrum where the critical thinking test is completed. The two distinct points that were studied are students at the beginning of their formal medical dosimetry educational program (entry-level students) and practicing medical dosimetry professionals. Additional independent variables included age, gender, ethnicity, educational degree, RTT status, years experience in clinical

healthcare and medical dosimetry, type of prior work experience, years

medical dosimetry training, type of clinical medical dosimetry education, and

environment of clinical medical dosimetry education and training.

The dependent variables were the HSRT total score and its five sub-

scale scores; deductive, inductive, analysis, inference, and evaluation.

Instrumentation.

The HSRT was developed specifically for assessing critical thinking

ability of health science students and professionals. It is a multiple-choice

test with 33 items that takes about 50 minutes to administer. The HSRT is

available in paper and electronic versions. The items were pooled from the

questions on the California Critical Thinking Skills Test (CCTST) and the

California Disposition Inventory, but were modified to use mini-cases and

vignettes common to the healthcare workplace. It has been used to test over

3000 health science students and professionals in a variety of clinical

professions (Facione, 2009).

While the HSRT is a relatively new test, it is a valid and reliable tool for

measuring critical thinking skills. Content, construct, and criterion validity

have been addressed (Facione, 2013, Giddens & Gloeckner, 2005, Vendrely,

2005, Vendrely, 2007, Williams, et al, 2003). The HSRT test items measure

the specific domain of critical thinking as cognitive skills identified in the APA

Delphi report; interpretation, analysis, evaluation, explanation, and inference

(Facione, 1990). According to Insight Assessment, the distributor of the test,

psychometric item analysis was used to examine responses to the items (Facione, 2013). Evidence is also provided by demonstrated improvement in scores after students take a course in critical thinking (Giddens & Gloecker, 2005, Vendrely, 2005, Vendrely, 2007, Williams, et al, 2003). A study by Huhn, et al. (2011) further contributed to the construct validity of the test by testing novice, as defined by students in the first year of their physical therapy education and certified clinical physical therapy specialists. The total HSRT total score of the expert group was significantly higher (24.06) than the novice group (22.49), thus confirming that the test measures what it claims to measure (t(148) = -2.67, p = .008). While the HSRT is the newest test in the family of California critical thinking tests, research studies report that the CCTST demonstrated strong correlations with other standardized college level tests, like the GRE, thus leading one to infer that the HSRT would also strongly correlate with GRE. The overall Kuder-Richardson-20, which is comparable to the Cronbach's alpha for dichotomously scored instruments, is 0.81. Internal consistency for the HSRT subscales were stable in the 0.6-0.8 range, which is more than adequate to support placing confidence in each of the scales. (Facione, 2013)

Insight Assessment reports a total score and five sub-scale scores for the HSRT. According to Insight Assessment, the total HSRT score is the strongest indicator of critical thinking skills and is scored on a scale from 0 to 33 (Facione, 2013). A score of 15 or less is categorized as an extremely

weak critical thinking score or not manifested because the score was influenced by a confounding factor, such as insufficient test-taker effort, cognitive fatigue, or reading or language comprehension issues. A score between 16 and 21 reflects an individual with a moderate core critical thinking skills. In this range, the individual has the potential for critical thinking skills, but may encounter challenges when engaged in reflective problem solving or decision-making. A score between 22 and 26 is indicative of an individual with strong core critical thinking skills and the potential for academic success and career development. A score above 26 is consistent with an individual with superior critical thinking skills, who has the potential for advance learning and leadership. The 50th percentile national norm for all two and four year health science graduates total HSRT score is 20.0 and for all practicing health science professionals is 22.9.

The five HSRT sub-scale scores are meant to identify relative strengths or weaknesses in a particular area of critical thinking; inductive, deductive, analysis, inference, and evaluation. The deductive and inductive subscales are scored on a scale of 0 to 10 and the analysis, evaluation, and inference subscales are scored on a scale of 0 to 6. Each sub-score scale is divided into three ranges, low or not manifested, moderate, and strong. For deductive and inductive sub-scales, the weak, or not manifested, range is a score of 5 or less, the moderate is between 6 and 8 and the strong range is a score greater than 8. For the analysis, evaluation, and inference subscales,

the weak, or not manifested, range is 2 or less, the moderate is between 3 and 5, and the strong range is a score greater than 5 (Table 2).

An individual who has strong inductive skills has the ability to consider all possibilities, even if some might lead to the wrong conclusion. Strong deductive skills are indicative of an individual who makes decision based on logic following well-established rules or guidelines. An individual who scores in the strong category for analysis gathers information to make decisions. Strong inferential thinkers draw probable conclusions using not only the evidence that is presented, but also the evidence that is absent. A strong inferential thinker will consider all options, drawing on logic and reason to make a decision. Lastly, strong evaluation skills are based in assessment of the quality of the evidence. An individual who scores in the strong category will weigh the credibility of the argument before making a decision.

After obtaining Seton Hall University Investigation Review Board approval, a solicitation letter was sent by the AAMD to all members of the organization to voluntarily participate in the electronic version of the survey, which included a demographic survey and the HSRT.

Table 2

Health Sciences Reasoning Test Scoring Scheme

Total HSRT	Score Range	Description
	0-15	Extremely weak CT skills Or Not manifested
	16-21	Moderate CT skills
	22-26	Strong CT skills
	>26	Superior CT skills
Sub-scale	Range	Description
Deductive	0-5	Not manifested
	6-8	Moderate CT skills
Inductive	>8	Strong CT skills
Analysis	0-2	Not manifested
Inference	3-5	Moderate CT skills
Evaluation	>5	Strong CT skills

Sample.

The sample of convenience in this study included all males and females, 18 years old or older. Additionally, the sample were either entry-level medical dosimetry students enrolled in a formal medical dosimetry educational program or medical dosimetry professionals who are currently practicing medical dosimetry. All participants voluntarily participated in this study. Subjects excluded from the study include those who were less than 18 years old, students enrolled in other formal educational programs other than medical dosimetry, medical dosimetrists enrolled in a clinical "on-the-job" training program, or medical dosimetry professionals who are not currently practicing medical dosimetry.

A priori power analysis was performed to determine the sample size to meet a power of 0.80. Using a medium effect size (d=0.5) and alpha of 0.05, the G-power analysis required a sample size of 51 in each group, or 102 total subjects. (Faul, 2006,2009). The sample size assumed a normal distribution and therefore parametric statistics were used for analysis. When normality was not achieved, nonparametric statistics were used for analysis.

Chapter IV

Results

Characteristics of the Sample.

The target population was the entire membership of the American Association of Medical Dosimetrists (AAMD) (n=2508) and all entry-level Medical dosimetry students enrolled in a formal educational program (n=166). The AAMD reported a 50% "open" rate for emails, so the author assumed an accessible population of half the target population (n=1254). For purposes of analysis, the total number of subjects who completed the demographic survey was 155. One hundred twenty-four subjects completed at least 60% of the items on the HSRT, which is required to score the test effectively. Three subjects were not categorized resulting in 121 subjects being available for analysis (N=121). Sixty-three subjects were entry-level medical dosimetry students and 58 were practicing medical dosimetry professionals.

The mean age of the overall sample was 37.3, the mean age of the student population was 25.5, and the mean age of practicing professional population was 44.5. The age distribution of the entry-level student sample was positively skewed, while the age distribution of practicing medical dosimetry professional sample was negatively skewed (Figure 1).

The gender split among females and males for the total sample was 58 females (55%) and 48 males (45%). Fifteen subjects did not respond to the gender-identifying question. Eighty-four subjects (80%) self-reported their

Age
■ Med Dos Students (N=60, M=25.5)a
■ Med Dos Professionals (N=56, M=44.5)
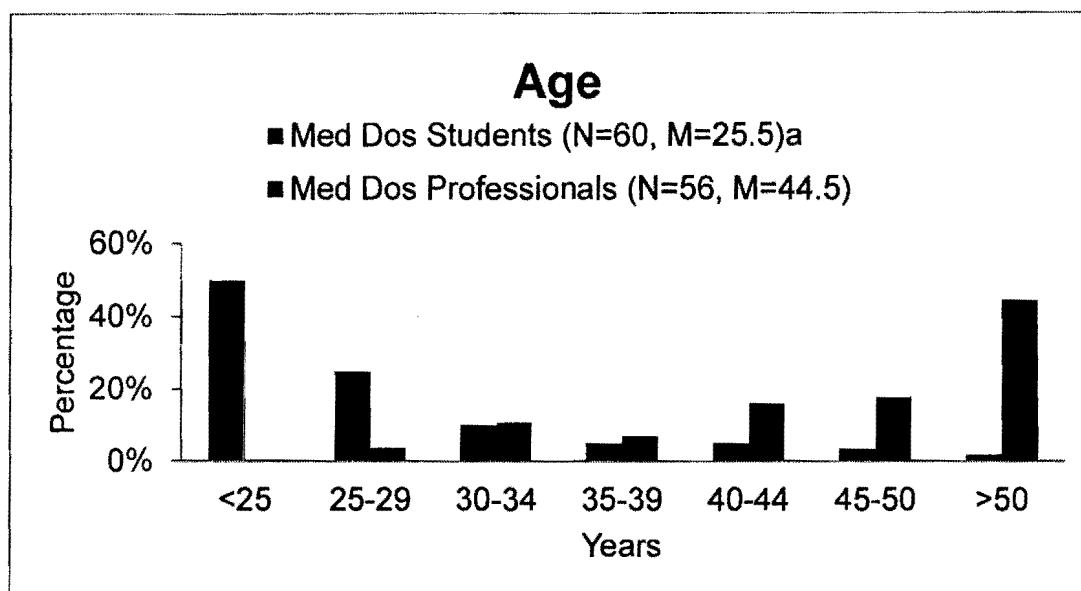
[a]Data presented as percentage of subjects within the groups. Three subjects from the student group did not disclose age.

Figure 1. Age distribution of entry-level Medical Dosimetry students and Medical Dosimetry professionals.

ethnicity as Caucasian, 11 subjects(10%) self-reported as Asian-American/Pacific Islander, 3 subjects (3%) self-reported as Hispanic, Latino, or Mexican American, 7 subjects (7%) self-reported as Other, and 16 subjects chose not to answer this question. Table 3 lists the gender and ethnicity between groups.

Twenty-nine subjects (24%) reported that their highest level of formal education achieved was less than a Bachelor's degree; 22 subjects (18%) had at least an Associate's Degree and 7 subjects (6%) had no more than a High School Degree, or equivalent. Ninety-two subjects (76%) reported that they had a minimum of a Bachelor's Degree, with 4 subjects (3%) having a Masters Degree. Eighty-eight subjects (74%) were previously trained or practiced as an RTT and 31 subjects (26%) were not. Two subjects did not report their RTT status. These data are depicted in Table 4 between the groups.

Nineteen subjects (16%) reported no healthcare experience at the time of the survey, 13 subjects (11%) reported less than 2 years experience, and 17 subjects (14%) reported between 3 and 5 years experience. Eighteen subjects (15%) reported between 6-10 years experience, 6 subjects (5%) reported between 11-15 years experience, 13 subjects (11%) reported between16-20 years experience, and 33 subjects (28%) reported more than 20 years of clinical healthcare experience. These data are depicted in Figure 2 between the groups.

Table 3.

Gender and Ethnicity Demographics Comparison Between Subjects in Both Groups (n=121)

		Med Dos Students (n=50)[a]	Med Dos Professionals (n=56)[b]	Total Sample (n=106)[c]
Gender	Male	27 (54%)	21 (38%)	48 (45%)
	Female	23 (46%)	35 (63%)	58 (55%)
		Med Dos Students (n=48)[d]	Med Dos Professionals (n=57)[e]	Total Sample (n=105)[f]
Ethnicity	Anglo American Caucasian	30 (63%)	54 (95%)	84 (80%)
	Asian American Pacific Islander	10 (21%)	1 (2%)	11 (10%)
	Hispanic, Latino Mexican American	3 (6%)	0 (0%)	3 (3%)
	Other	5 (10%)	2 (3%)	7 (7%)

[a]Data are presented as number of subjects (percentage) within the group. Thirteen subjects in the student group did not disclose gender. Some totals do not add up to 100% due to rounding errors. [b]Two subjects within the professional group did not disclose gender. [c]A total of 15 subjects did not disclose gender. [d]Fifteen subjects in the student groups did not disclose ethnicity. [e]One subject in the professional group did not disclose ethnicity. [f]A total of 16 subjects did not disclose ethnicity.

Table 4.

Education and RTT Status Demographics Comparison Between Subjects in Both Groups (n=121)

		Med Dos Students (n=63)	Med Dos Professionals (n=58)	Total Sample (n=121)
Highest Earned	Less than a Bachelor's Degree	8 (13%)[a]	21 (36%)	29 (24%)
	Minimum of a Bachelor's Degree	55 (87%)	37 (64%)	92 (76%)
		Med Dos Students (n=61)[b]	Med Dos Professionals (n=58)	Total Sample (n=119)[c]
RTT Status	Prior training and/or practice as RTT	37 (61%)	51 (88%)	88 (74%)
	No prior training or practice as RTT	24 (39%)	7 (12%)	31 (26%)

[a]Data are presented as number of subjects (percentage) within the group..
[b]Two subjects within the student group did not disclose RTT status. [c]A total of 2 subjects did not disclose RTT status.

Healthcare Experience

■ Med Dos Students (N=61)a

■ Med Dos Professionals (N=58)
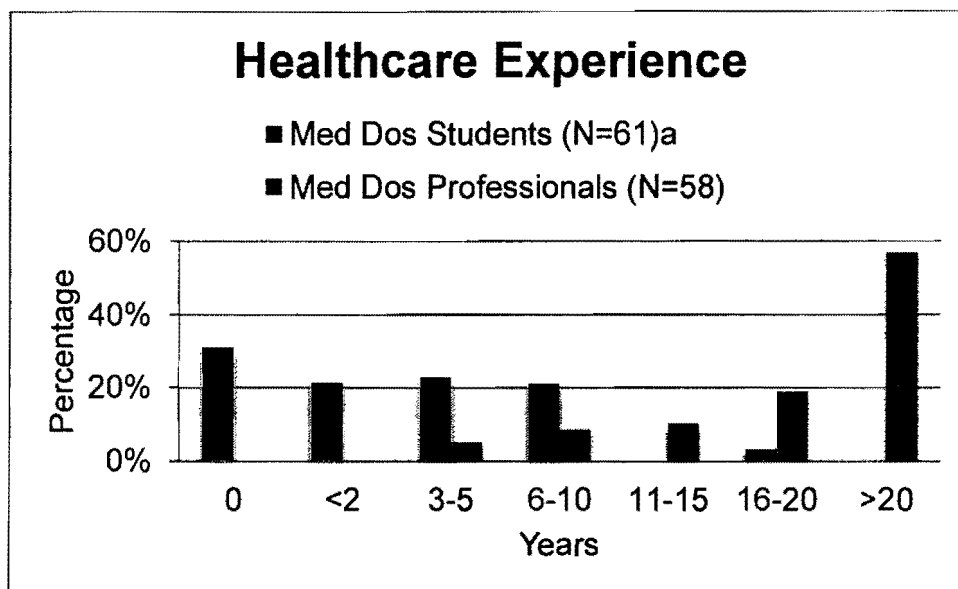
[a]Data are presented as percentage of subjects within the group. Two subjects in the student group did not disclose healthcare experience.

Figure 2. Healthcare Experience of Subjects in Both Groups.

Ten subjects (10%) reported that medical dosimetry was their first career, 1 subject (1%) reported a prior nonclinical profession, and 4 subjects (4%) reported that they had another profession before entering medical dosimetry. Five subjects (5%) reported prior experience in radiologic technology and 9 subjects (9%) reported experience in some other clinical healthcare profession. The overwhelming majority of subjects, 77 (73%) reported previous experience as radiation therapists (RTT) prior to entering medical dosimetry. These data are displayed in Table 5.

Further reviewing the demographic data of the practicing medical dosimetry population, the following were noted. One subject (2%) reported less than 2 years medical dosimetry experience at the time of the survey, 7 subjects (12%) reported between 3-5 years, 9 subjects (16%) reported between 6-10 years, and 17 subjects (29%) reported between 11-15 years medical dosimetry experience. Four subjects (7%) reported between16-20 years medical dosimetry experience and 18 subjects (31%) reported greater than twenty years. Two subjects chose not to answer the medical dosimetry experience question.

Fifty-eight practicing medical dosimetry professionals reported on the location of their medical dosimetry experience. Fourteen (24%) subjects reported their experience was primarily in a community hospital, 20 (34%) reported their experience in a freestanding center, and 13 (22%) subjects reported their experience was in a hospital network. Ten (17%) subjects

Table 5.

Prior Career Comparison Between Subjects in Both Groups (n=121)			
	Med Dos Students (n=48)[a]	Med Dos Professionals (n=58)	Total Sample (n=106)[c]
Medical Dosimetry as First Career	6 (13%)	4 (7%)	10 (9%)
Radiologic Technology (RT)	2 (4%)	3 (5%)	5 (5%)
Radiation Therapy Technology (RTT)	29 (60%)	48 (83%)	77 (73%)
Other Clinical Healthcare Profession	8 (17%)	1 (2%)	9 (8%)
Other Nonclinical Healthcare Profession	1 (2%)	0 (0%)	1 (1%)
Other	2 (4%)	2 (3%)	4 (4%)

[a]Data are presented as number of subjects (percentage) within the group rounded to the nearest whole number. Some totals add to greater than 100% due to rounding errors. Fifteen subjects within the students' group did not disclose prior career. [b]A total of 15 subjects did not disclose prior career.

reported their experience in an academic center and 1 subject (2%) reported experience in another type of clinical environment. Length and location of experience data are depicted in Table 6.

Length and location of experience data are depicted in Table 6.There were three demographic questions with respect to medical dosimetry education and training. Twenty two (39%) practicing professionals reported attending a formal medical dosimetry educational program; 11 subjects (19%) attended a JRCERT accredited program or a program which is in the progress of becoming accredited by JRCERT and 12 subjects (21%) attended a non-accredited program or did not know if the program was accredited. Thirty-five practicing medical dosimetry professionals reported not attending a formal educational program as part of their training. These data are depicted in Table 7.

Eight practicing medical dosimetry professionals (14%) attended a certificate program, 1 (2%) attended an Associate's degree program, 2 (3%) attended a Bachelor's degree program, and 47 (81%) identified their training as on-the-job (OTJ). Nine subjects (16%) spent 3 years in medical dosimetry training, 24 (41%) spent 2 years, 13 (22%) spent only 1 year in training, and 4 (7%) reported that they did not spend any time in medical dosimetry training. The rest of the professional sample (n=8, 7%) reported spending greater than 3 years in medical dosimetry training (see Table 7).

Table 6.

Length and Location of Medical Dosimetry Experience (including Training) of Practicing Medical Dosimetry Professionals (n=58)

Length of Experience (years) (n=56)[a,b]		Location of Experience (n=58)	
<2 years	1 (2%)	Community Hospital	14 (24%)
3-5 years	7 (13%)	Freestanding Clinic	20 (34%)
6-10 years	9 (16%)	Hospital Network	13 (22%)
11-15 years	17 (30%)	Academic Institution	10 (17%)
16-20 years	4 (7%)	Other	1 (2%)
>20 years	18 (32%)		

[a]Data are presented as number (percentage) of subjects within the group. Percentages do not add up to 100% due to rounding errors. [b]Two subjects did not report length of experience.

Table 7.

Educational Program Attended, Type of Medical Dosimetry Training, and Length of Training of Practicing Medical Dosimetry Professionals (n=58)

Status of Educational Program Attended	
JRCERT Accredited or In Progress	11 (19%)[a]
Non-Accredited Program or Don't Know	12 (21%)
Did not attend a program	35 (60%)
Type of Medical Dosimetry Training	
On-the-Job Training	47 (81%)
Certificate Program	8 (14%)
Associate's Degree	1 (2%)
Bachelor's Degree	2 (3%)
Masters Degree	0 (0%)
Length of Medical Dosimetry Training (years)	
None	4 (7%)
1 year	13 (22%)
2 year	24 (41%)
3 years	9 (16%)
4 years	2 (3%)
5 years	1 (2%)
>5 years	5 (9%)

[a]Data are presented as number (percentage) of subjects within the group.

Assessment of Critical Thinking.

The medical dosimetry practicing professional (n = 58) descriptive statistics were as follows; total HSRT score (M = 20.3, SD = 4.0), inductive sub-scale score (M = 7.6, SD =1.5), deductive sub-scale score (M = 6.0, SD = 1.9), analysis sub-scale score (M = 4.2, SD = 1.3), inference sub-scale score (M = 2.5, SD = 0.9), and evaluation sub-scale score (M = 4.9, SD = 1.1). Based upon these scores, the author rejected the null hypothesis for research question #1. The data supported that the total critical thinking skills of practicing medical dosimetry professionals were not in the strong range, but rather in the moderate range, as measured by the HSRT. These data are depicted in Table 8.

Descriptive statistics of the entry-level medical dosimetry student group (n = 63) were as follows; total HSRT score (M = 21.3, SD = 4.3), inductive sub-scale score (M = 7.7, SD = 1.5), deductive sub-scale score (M = 6.2, SD = 2.0), analysis sub-scale score (M = 4.3, SD = 1.2), inference sub-scale score (M = 3.1, SD = 1.1), and evaluation sub-scale score (M = 5.1, SD = 1.1). Based upon these scores, the author rejected the null hypothesis for research question #2. The total critical thinking skills of entry–level medical dosimetry students were not in the moderate range, but rather in the strong range, as measured by the HSRT. (Table 8)

According to Insight Assessment, Inc., the total HSRT score is the best indicator of overall critical thinking skills (Facione, 2013). The HSRT Test

Table 8.
Critical Thinking Scores Between the Subjects of the Groups (n=121)

Variable	Mean	Median	Mode	SD	SEM	Min	Max
Medical Dosimetry Professionals (n=58)							
Total Score	20.3	21.0	21,22[a]	4.0	0.52	11	27
Sub-scale Scores							
Inductive	7.6	8.0	8	1.5	0.20	4	10
Deductive	6.0	6.0	6	1.9	0.25	1	9
Analysis	4.2	4.0	5	1.3	0.17	2	6
Inference	2.5	3.0	3	0.9	0.12	0	4
Evaluation	4.9	5.0	6	1.1	0.15	2	6
Entry-level Medical Dosimetry Students (n=63)							
Total Score	21.3	22.0	20	4.25	0.54	6	29
Sub-scale Scores							
Inductive	7.7	8.0	8	1.45	0.19	2	10
Deductive	6.2	6.0	7	1.96	0.25	1	10
Analysis	4.3	4.0	5	1.20	0.15	1	6
Inference	3.1	3.0	3	1.08	0.14	0	5
Evaluation	5.1	5.0	5	1.08	0.14	1	6

[a]Multilple modes

Manual (2013) recommended categories for the scores are weak, or not manifested, moderate, strong, and superior (see Table 2). The weak, or not manifested category describes individuals who have extremely weak critical thinking scores, did not commit adequate effort to finish the test, or were presented with one or more challenges during taking the test. These challenges may include reading comprehension, language issues, or fatigue. To address some of these test-taking factors, when Insight Assessment, Inc. returns the results to the investigator, subjects who take less than 20 minutes to complete the test and/or answer less than 60% of the questions are eliminated from analysis. This increases the accuracy of the test results in the weak, or not-manifested category. The moderate category describes individuals with average critical thinking skills. The strong category describes individuals that have above average critical thinking skills, consistent with individuals who pursue academic endeavors. The superior category indicates an individual with excellent critical thinking skills, who have the potential to pursue advanced education and learning (Facione, 2013).

The total HSRT score of the practicing medical dosimetry professional group (M = 20.3) was in the moderate category, which indicates that this sample group has average critical thinking skills, but may incur challenges with problem solving or decision making that requires intuitive, insightful, or reflective thinking. The total HSRT score of the entry-level medical dosimetry student group (M = 21.3) was in the strong category, which describes this

sample group as consistent with an individual who will likely be successful in an academic setting and with career development. Figure 3 displays the box plots comparing the total HSRT scores for both groups.

Independent t-test was used to compare the total HSRT scores and all five sub-scale scores for the two groups. The difference between the two groups was not significant for the total HSRT, $t(119) = 1.31$ $p = .096$ (one-tailed), and four of the five sub-scale scores; inductive, $t(119) = 0.52$, $p=.301$ (one-tailed) deductive, $t(119) = 0.41$, $p = .343$ (one-tailed), analysis, $t(119) = 0.22$, $p = .413$ (one-tailed), and evaluation, $t(119) = 0.59$, $p = .279$ (one-tailed). Only the inference score returned a significant difference, $t(119) = 3.34$, $p < .001$ (one-tailed), $d = .60$ between the groups. When looking between groups, the entry-level student group ($M = 3.1$, $SD = 4.3$) demonstrated stronger inference skills than the professional group ($M = 2.5$, $SD = 0.9$). (Table 9)

The findings of this study enable the author to retain the null hypothesis for the total HSRT score and four of the five sub-scale scores with only the inference sub-scale score supporting a rejection of the null hypothesis.

Post-hoc analysis was completed for the parameters collected in the demographic survey. Using ANOVA, no significant difference was seen in the total HSRT scores or four of the five sub-scale scores versus age. Inference scores were significantly greater for those individuals less than 25 years of age ($M = 3.33$, $SD = 3.55$) compared to the 31-35 year old group ($M = 2.08$,
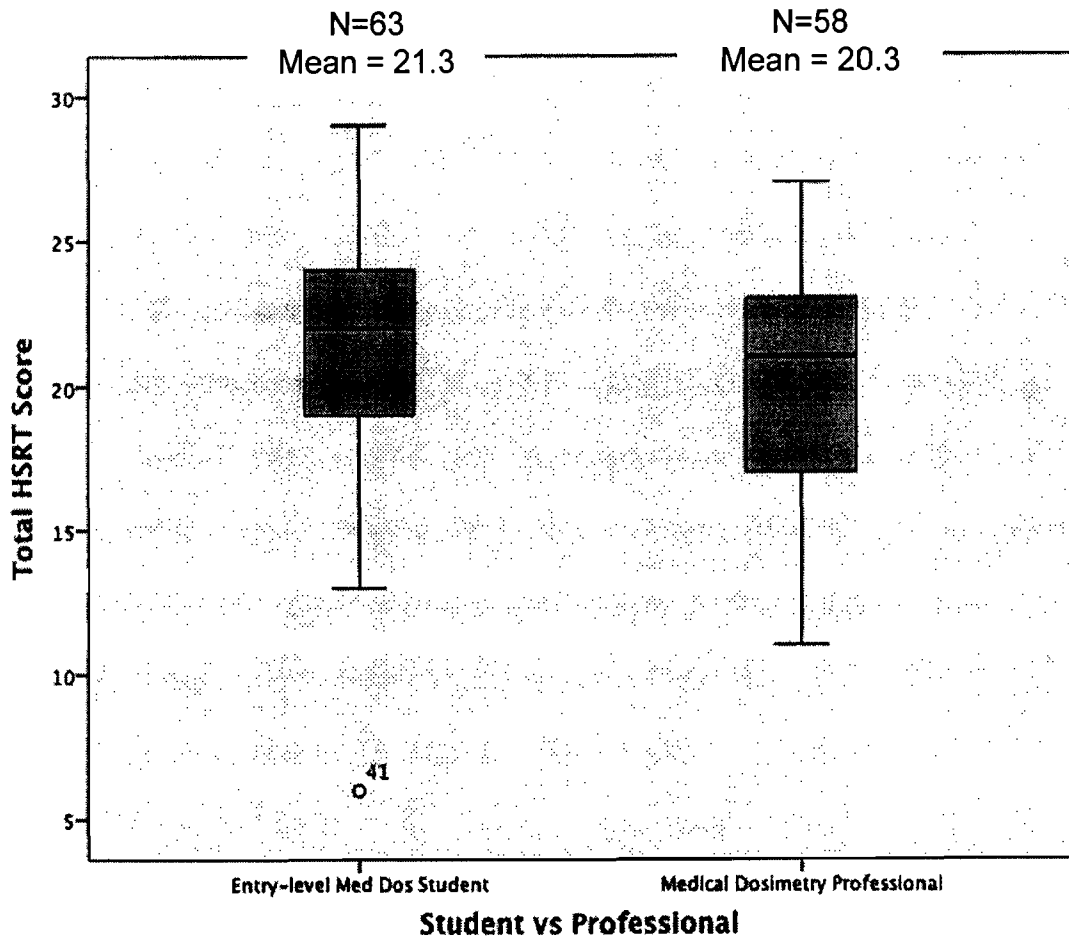
Figure 3. Box plot of total HSRT Scores for entry-level medical dosimetry students and medical dosimetry professionals.

Table 9.

Comparison of Critical Thinking Scores Between the Subjects of the Groups Based on Professional Status. (N = 121)

	Practicing Medical Dosimetry Professionals (n = 58)	Entry-level Medical Dosimetry Students (n = 63)	t	Sig. (1-tailed)	d**
	Mean				
Total Score	20.3	21.3	1.31	.096	ns
	Sub-scale Scores				
Inductive	7.6	7.7	.52	.301	ns
Deductive	6.0	6.2	.41	.343	ns
Analysis	4.2	4.3	.22	.413	ns
Inference	2.5	3.1	3.34	< .001*	.60**
Evaluation	4.9	5.1	.59	.279	ns

*Significance is 0.05

**$1 - \beta \geq .80$

SD = 5.57) and the greater 50 year old group (M = 2.39, SD = 3.91), F (6,119) = 3.454, p = .004, d = .95.

The group of subjects with a minimum of a Bachelor's degree (n = 92, Mean Rank = 66.0) had significantly stronger total critical thinking skills than those with less than a Bachelor's degree (n = 28, Mean Rank = 42.5), z = 3.14, p < .001, d = .65. A significant increase was also seen in only one of the sub-scale scores. The group of subjects with a minimum of a Bachelor's degree (Mean Rank = 64.8) had significantly stronger inference scores than those with less than a Bachelor's degree (Mean Rank = 46.4), z = 2.56, p = 0.005, d = .58. (Table 10) The difference in critical thinking skills with education in this study is consistent with literature (Starkey & Henderson, 1995, Williams & Hadfield, 2003, Raymond & Washington, 2002, Asprey, Dehn, Kreiter, 2004).

Seventy two percent of the subjects were previously trained or practiced as RTT. Comparing the critical thinking scores of the two groups, they were not similar in size, so the Mann-Whitney U nonparametric statistic was used for analysis. The results indicated that individuals who were previously trained or practiced as an RTT (n = 87, Mean Rank = 53.5) had significantly weaker total critical thinking skills than those who had not trained or practiced in that profession (n = 31, Mean Rank = 76.3), z = -3.19, p < .001 d = .68. The deductive sub-scale score for the group of subjects that were previously trained or practiced ad an RTT (n = 87, Mean Rank = 55.0) was significantly

weaker than those who had not trained or practiced as an RTT (n = 31, Mean Rank = 72.3), z = -2.45, p = .007 d = .55. These data are depicted in Table 10.

Influences of medical dosimetry education and training were also explored for the medical dosimetry professional subjects. A group comparison between medical dosimetry professionals who attended a formal educational program (n = 23, Mean Rank = 31.4) and those who did not attend a formal educational program (N = 34, Mean Rank = 27.4) was not significant between the groups for the total score or any of the sub-scale scores (p > .189). (Table 11)

However, of the 23 practicing professionals who attended a formal medical dosimetry educational program, 11 attended a JRCERT accredited program and 12 attended a non-accredited program. The group of subjects who attended a JRCERT accredited program had significantly stronger total HSRT scores than those who attended a non-accredited program t = 2.72(21), p = .007, d = 1.12. A significant difference was also seen for the analysis sub-scale score. The group of subjects who attended a JRCERT accredited program had significantly stronger analysis scores than those who attended a non-accredited program t = 3.05(21), p = .004, d = 1.22. (Table 11)

There was no significant correlation between the groups of medical dosimetry professionals in years spent in medical dosimetry training, nor

Table 10

Comparison of Critical Thinking Scores Between the Subjects of the Groups Based on Education Level. (N=121)

	Minimum of a Bachelor's Degree (n=92)[a]	Less than Bachelor's Degree (n=28)	z	Sig. (1-tailed)*	d**
	Mean (Mean Rank)				
Total Score	21.4 (66.0)	18.8 (42.5)	3.14	< .001*	.65**
	Sub-scale Scores				
Inductive	7.8 (64.4)	7.3 (47.7)	2.29	.011	.34
Deductive	6.2 (63.3)	5.6 (51.5)	1.59	.056	ns
Analysis	4.4(63.4)	3.9 (51.0)	1.69	.046	.41
Inference	2.9 (64.8)	2.3 (46.4)	2.56	.005*	.58**
Evaluation	5.0 (63.2)	4.8 (51.8)	1.61	.054	ns
	Trained and/or practiced as an RTT (n=87)[b]	Never trained or practiced as an RTT (n=31)	z	Sig. (1-tailed)*	d**
	Mean (Mean Rank)				
Total Score	22.8 (76.3)	20.2 (53.5)	-3.19	< .001*	.68**
	Sub-scale Scores				
Inductive	7.5 (55.8)	8.1 (70.0)	-2.04	.021	.46
Deductive	5.8 (55.0)	6.8 (72.3)	-2.45	.007*	.55**
Analysis	4.2 (57.1)	4.6 (66.2)	-1.30	.097	ns
Inference	2.7 (56.0)	3.1 (69.4)	-1.96	.025	.40
Evaluation	4.9 (55.8)	5.4 (69.9)	-2.08	.019	.47

[a]One subject did not report the level of education [b]Three subjects did not report their RTT status.
*Significance is 0.05
**$1 - \beta \geq .80$

Table 11

Comparison of Critical Thinking Scores Between Subjects of the Groups Based on Attendance in a Medical Dosimetry Educational Program. (N=57)

	Attended a Formal Medical Dosimetry Educational Program (n = 23)	Did not Attend a Formal Medical Dosimetry Educational Program (n = 34)	z	Sig. (1-tailed)*	d**
	Mean (Mean Rank)				
Total Score	21.0 (31.4)	20.1 (27.4)	0.88	.189	ns
	Sub-scale Scores				
Inductive	7.8 (30.7)	7.5 (27.9)	0.64	.260	ns
Deductive	6.1 (30.2)	5.4 (28.2)	0.46	.325	ns
Analysis	4.2 (27.8)	4.3 (29.8)	-0.48	.317	.ns
Inference	2.4 (27.6)	2.6 (29.9)	-0.59	.273	.ns
Evaluation	5.0 (30.4)	4.9 (28.1)	0.55	.292	ns
	Attended a JRCERT Accredited Medical Dosimetry Educational Program (n = 11)	Attended a non-accredited Medical Dosimetry Educational Program (n = 12)	t	Sig. (1-tailed)*	d**
	Mean				
Total Score	22.9 (76.3)	19.2	2.72	.007*	1.12**
	Sub-scale Scores				
Inductive	8.3	7.3	1.92	.035	.85
Deductive	7.1	5.3	2.19	.021	.89
Analysis	4.8	3.6	3.05	.004*	1.22**
Inference	2.5	2.3	0.46	.326	.ns
Evaluation	5.3	4.8	0.94	.181	ns

*Significance is 0.05 **$1 - \beta \leq .80$

between groups of medical dosimetry professionals for level of education in a training program, which included on-the-job training programs. (Table 12)

There was a significant difference between groups for the total HSRT score and four of five sub-scale scores for prior work experience using the non-parametric Kruskal-Wallis Test. Bonferroni post-hoc analysis indicated that the difference is significant (p = .013) between two groups; first career subjects (n = 10, Mean Rank = 69.0) and subjects who previously practiced as Radiologic Technologists (n = 5, Mean = 27.0), H(3) = 8.59, p = .018, d = .80. There was also a significant difference in the total HSRT score between of subjects divided by the primary location of their medial dosimetry experience, H(4) = 11.63, p = 0.020, d = .80.

Forty-six subjects reported no medical dosimetry experience (Mean Rank = 60.7), 16 worked in a community hospital (Mean Rank = 62.2), 14 in an academic institution (Mean Rank = 72.1), 23 in a free-standing center (Mean Rank = 44.5), and 13 in a hospital network (Mean Rank = 39.0). A Bonferroni post-hoc analysis revealed that the total HSRT score was significantly stronger for the group that worked in an academic institution than the group who worked in a freestanding clinic (p = .050) and the group who worked in a hospital network (p = 0.039). Individuals who work in an academic environment may have more opportunities to teach, mentor, and participate in continuing education with colleagues compared to those who work in other clinical environments.

Table 12.

Analysis of Variance Between Three Groups of Medical Dosimetry Professionals for the Number of Years Spent in Medical Dosimetry Training; One Year or less, 2 Years, and 3 or More Years (N = 57)

Source	df	F	η	P*
Between Subjects				
Total HSRT Score	2	3.40	.11	.021**
Inductive Sub-scale Score	2	1.01	.04	.185
Deductive Sub-scale Score	2	1.93	.07	.078
Analysis Sub-scale Score	2	1.35	.05	.134
Inference Sub-scale Score	2	.16	.01	.421
Evaluation Sub-scale Score	2	.98	.03	.191

Analysis of Variance Between Four Groups of Medical Dosimetry Professionals for the Level of Education in a Medical Dosimetry Training Program; Certificate, Associate's Degree, Bachelor's Degree, and On-the-job Training (N = 58)

Between Subjects				
Total HSRT Score	3	3.39	.16	.013**
Inductive Sub-scale Score	3	1.48	.08	.115
Deductive Sub-scale Score	3	2.67	.13	.028**
Analysis Sub-scale Score	3	1.66	.08	.093
Inference Sub-scale Score	3	.88	.05	.229
Evaluation Sub-scale Score	3	1.16	.06	.118

*Significance is 0.05.

**$1 - \beta \leq .80$, therefore results are not significant.

Individuals in freestanding clinics and community hospitals are most likely sole practitioners.

There was a significant negative correlation between the number of years of clinical healthcare experience and total HSRT scores ($r = -.23$, $p = .012$, $d = .27$), which I will discuss in the next chapter. There was no significant correlation between the number of years of medical dosimetry experience and total HSRT scores ($r = -.06$, $p = .104$).

Chapter V

Discussion

This study is the first investigation exploring critical thinking skills of medical dosimetrists. According to Insight Assessment, the total HSRT score is the strongest indicator of critical thinking skills (Facione, 2013). As measured by the total HSRT scores, the critical thinking scores of practicing medical dosimetry professionals were in the moderate range (M = 20.3) and the critical thinking skills of entry-level dosimetry students were in the strong range (M=21.3). The null hypotheses were retained for the first two research questions. The medical dosimetry professionals exhibited weaker skills than expected and entry-level medical dosimetry students exhibited stronger skills than expected. Exploring the sub-scale scores for each group, all of the medical dosimetry professional sub-scale mean scores were in the moderate range. The same was true for the entry-level medical dosimetry students, except for evaluation, where the group scored in the strong range.

The null hypothesis is also retained for the third research question. There was no significant difference (p = .096) between the critical thinking skills of the medical dosimetry professionals compared to the entry-level medical dosimetry students, as measured by the total HSRT score.

Many authors studied critical thinking of health science professionals as a crucial part of training the health science professional to take acquired knowledge and skills and apply HSRT or the CCTST to assess these skills

(Vendrely, 2008, Huhn et al, 2012, Williams, et al, 2003, Giddens et al, 2005, Coker, 2010, Colt, 2007, D'Antoni, et al, 2010). Huhn, et al (2012) reported a significant increase (p = .008) of the total HSRT score between novice and expert physical therapists. Bartlett and Cox (2002) reported a significant increase (p < .010) in total CCTST scores of physical therapy students measured at two distinct points during the middle year of their clinical education. Vendrely (2005) reported no significant increase (p = .032) in composite CCTST scores of physical therapy entry-level students and at the end of their educational program, including didactic and clinical. Coker (2010) reported a significant increase (p = .006) in the total CCTST score of occupational therapy students before and after a one-week experiential learning program.

This study also compared the critical thinking skills to two health science professionals; physician assistants (PA) and physical therapists (PT). The PA profession is similar to medical dosimetry, as both groups of professionals perform their day-to-day tasks independently and review their results with a physician before continuing with the care of a patient. The PA will take a medical history, examine the patient, and gather information and possible diagnosis for presentation to the physician. The medical dosimetrist will create a radiation treatment plan independently and review their results with a physician before implementing the treatment plan. It might be expected that medical dosimetrists and the PA have similar critical thinking skills.

Physical therapists, on the other hand, practice autonomously. They are trained and practice as independent practitioners who make clinical decisions without the supervision of a physician. If might be expected that PTs have stronger critical thinking skills than medical dosimetrists.

Practicing medical dosimetry professionals scored significantly lower than physical therapy experts (24.1) (t=-7.36 (df57), p < .001) (Huhn, et al, 2012). The practicing medical dosimetry professional sample mean total HSRT score was also significantly lower (t=-5.05 (df57, p < .001) than the national norm for all health science professionals, as reported by Insight Assessment (Insight Assessment, 2013). Similar results were returned for all of the sub-scale scores for the group.

Entry-level medical dosimetry students scored significantly lower than physical therapy novices (M = 22.5, t =- 2.30(61), p = .013), but significantly the same as physician assistant students (M = 20.5, t = 1.41(61), p = .083) (Huhn, et al, 2012, Lowy, n.d.). The total HSRT national norm score (50th percentile) for both 2-year and 4-year health science graduates as 20.0 (Insight Assessment, 2013). The entry-level Medical Dosimetry student total HSRT mean score was also significantly higher (t=2.33 (61), p = .011) than the national norm.

Evaluating the five sub-scale scores there was no significant difference between the medical dosimetry professionals and the entry-level medical dosimetry students for four of the five sub-scale scores; inductive (p = .301),

deductive (p = 343), analysis (p = .413), and evaluation (p = .279). There was, however, a significant difference (p = <.001) between the groups for the inference score, where the entry-level medical dosimetry students exhibited stronger inference skills than the medical dosimetry professionals.

Inference skills enable us to draw conclusions from both evidence and reason. Inferential thinking incorporates not only facts, but also one's beliefs, especially when there is a lack of evidence. When information is limited or not explicitly stated, we draw a conclusion based on what one thinks is most probably true. Inferential reasoning is counter-intuitive to real science. As long as all of the facts or evidence are present, one does not have to infer the conclusion, but rather use the observations and known theories to make the decision. But when the evidence is not present or the evidence is incomplete, or a theory to explain a conclusion is not well known, one must rely on "reading between the lines" and make one's decision based on inferential reasoning. Low inference scores may be the result of reaching a conclusion that is biased or wrongly assuming a condition must be false because it has not been stated to be true. Without strong inference skills, lack of evidence, hasty conclusions, or generalizing conditions may lead to the wrong decision. Students do not have a wealth of experience and therefore are not biased in their decision-making. When they see regularity, they might use a logical reasoning approach to infer their conclusion, rather than be biased by their previous experiences. Students, therefore, rely on those patterns and

repeated experiences to come to conclusions, which is more likely common to the analytical though processes employed by professionals.

Mattingly (1991) proposes as one becomes experienced in one's profession, much of one's clinical decisions reflect habitual ways of seeing and dealing with patients. Our decisions become automatic. Novices do not have the same depth of knowledge nor do they have the benefit of experience. The results of this study might suggest that medical dosimetry students (novices) rely more on inferential reasoning to draw conclusions as compared to medical dosimetry professionals (experts).

Several authors reported significant differences in the critical thinking sub-scale scores. Huhn, et al (2012) found significant increases in the analysis scores (p < .001) and deductive scores (p = .010) between novice and expert physical therapists using the HSRT. Coker (2010) reported significant increases in the evaluation scores (p = 0.039) and deductive scores (p = .046) of occupational students before and after a one-week experiential learning program using the CCTST. Bartlett and Cox (2002) used the CCTST and reported significant increases (p < .040) in all sub-scale scores between different points in students' educational program.

Several authors studied decision-making in novice and expert individuals (Wainwright, et al, 2011 and Besnard & Bastien-Toniazzo, 1999). Besnard and Bastien-Toniazzo explored problem-solving performances of novices and experts in electronics. The study was limited due to the number

of subjects, but although the experts identified the error in the circuit before the novices, their decisions were based on knowledge and expertise, while the novice decisions were based on inference. Wainwright, et al (2011) did a qualitative study comparing factors that influence clinical decision-making in novice and experienced physical therapists. While both groups consistently relied on clinical experience, continuing education, and mentorship, novice physical therapists made clinical decisions based on informative factors; knowledge, reflection, and value of outcome. Experienced physical therapists relied on directive factors; medical record information, protocols, and observation. This research supports the significant decrease of inference skills found with experience in the present study. This suggests that as experience increases, evidence-based skills increase, while reflective, value related thinking decreases in decision-making.

The negative correlation between critical thinking skills and experience may follow the theoretical framework of Tversky and Kahneman (1981). Practicing professionals may frame their decision-making more based on clinical experience and protocols, rather than on personal, reflective thinking. Tversky and Kahneman (1981) theorized that decisions are made based partly on the formation of the problem and partly on personal norms, habits, and characteristics of the decision maker. The decision maker is influenced by the variations of the frame of the question and the risks associated with the outcomes. This theoretical framework may suggest that decisions are based

not only in evidence, but also in reason and consideration of all options, even if the final conclusion is not correct.

Literature includes other studies of physical therapy and occupational therapy students utilizing the CCTST before and after an educational intervention or experience. These studies all returned significant increases in composite CCTST scores (Vendrely, 2005, Bartlett & Cox, 2002, and Coker, 2010). Vendrely (2005) used a one-group pretest-posttest design and reported a significant increase (p = .032) in the composite CCTST scores of PT students as entry-level students and at the end of their academic program. Bartlett and Cox (2002) used a one-group repeated measures design and reported a significant increase (p < .001) on the CCTST between PT students over academic and clinical portions of their study. Coker (2010) reported a significant increase (p = .006) in CCTST total critical thinking skills after occupational therapy students participated in an experience-based learning program. Perhaps medical dosimetrists may benefit from educational opportunities that enhance critical thinking skills, like problem-based learning modules, case studies, or experiential-based programs.

Consistent with literature, the medical dosimetry sample with greater than a Bachelor's degree exhibited significantly stronger (p < .001) total critical thinking skills than those with less than a Bachelor's degree. This supports the direction of the education of future medical dosimetrists. Certification eligibility requirements increase to a minimum of a Bachelor's

degree beginning in 2017.

Traditionally, medical dosimetry was an advanced practice of radiation therapy technology. RTTs are trained as technicians to deliver the daily radiation treatments. These individuals may have knowledge and skills similar to medical dosimetrists, but as shown by this study, they do not possess strong critical thinking skills. Those individuals who previously trained or practiced as radiation therapists had significantly weaker ($p < .001$) critical thinking skills than those who did not train or practice as radiation therapists. This study provides a meaningful result for the medical dosimetry community and provides support for the certification eligibility requirement that eliminates the RTT route of eligibility in 2015.

Another significant finding of this study is the negative correlation between critical thinking skills and total healthcare experience ($r = -.23$, $p = .012$, $d = .27$). This result illustrates that experience, alone, is not enough to maintain a level of critical thinking achieved as a student. To maintain MDCB certification, medical dosimetrists must complete at least 50 continuing education credit hours approved by the MDCB in a five-year cycle. This study might suggest that the type of continuing education for medical dosimetrists might need to change to enhance critical thinking. Coker (2010) reported that critical thinking scores of occupational therapy students significantly increased ($p < .001$) after participating in an experiential learning opportunity.

Finally, it is not surprising that medical dosimetry professionals who

attended JRCERT accredited educational programs had significantly stronger (p = .007) critical thinking skills than those who attended non-accredited programs. JRCERT is the only agency recognized by the United States Department of Education and the Council for Higher Education Accreditation for accreditation of educational programs in the radiologic technology professions, including medical dosimetry (JRCERT, 2013). One of the standards requires programs to follow a standard curriculum that promotes clinical competence and good decision-making skills, which is reflective of critical thinking. This is supported by literature in other health science professional education (Harrelson et al., 1997; Starkey & Henderson, 1995; Vendrely, 2007; Yin & Burger, 2003).

Chapter VI

Summary and Conclusions

Medical dosimetry is a relatively new and unique health science profession. Medical dosimetrists engage in the practice of radiation treatment planning using very sophisticated, complex computerized three-dimensional treatment planning computers. They work independently in radiation oncology clinics and make crucial clinical decisions deciding the energy, direction, and size of the radiation beams that are used to treat cancerous tumors. Professional education, training, and certification requirements of medical dosimetrists are emerging and the new requirements come with much controversy amongst practicing professionals (AAMD, 2012). Little research exists on the population and no research addresses the critical thinking ability of this population.

While the sample size was small (n=121), this study did establish the HSRT as an appropriate tool to measure critical thinking skills of medical dosimetry professionals and entry-level students.

Compared to the national norm for all health science professionals who have taken the HSRT, practicing medical dosimetry professional scores were significantly lower (t = -5.05 (57) p < .001), thus leaving an opportunity to further investigate why and how critical thinking skills within the medical dosimetry population can be developed more effectively so that they can function as independent practicing professionals. The medical dosimetry

professional sample mean score was significantly lower (t =-7.36 (57) p < .001) than physical therapy experts. Given that physical therapists practice autonomously, one would expect that they demonstrate stronger critical thinking skills than those health care professionals who practice with supervision, such as medical dosimetrists. This study further supports the need for continued supervision by radiation oncologists and medical physicists. Further research with a larger sample size of the medical dosimetry population would allow for generalization of the data.

The entry-level medical dosimetry student mean sample critical thinking score was significantly the same as physician assistant students (t = 1.41(61), p = .083). PAs are also considered as independent health science professionals and it is valid to compare the two professions. The entry-level medical dosimetry sample mean score was significantly lower (t =- 2.30(61), p = .013) than physical therapy novices. This result is expected, as physical therapists are trained to practice autonomously and medical dosimetrists are trained to practice under the supervision of medical physicists and radiation oncologists. The entry-level medical dosimetry student population is also significantly higher (t=2.33 (61), p = .011) than the national norm for both 2-year and 4-year health science graduates. The student sample represented close to 50% of the target student population, so it is generalizable to the entry-level medical dosimetrists student population. A longitudinal research study following students throughout the learning spectrum conducted in the

near future may yield meaningful information about the effectiveness of type of learning environment or teaching techniques within a program.

This study provides meaningful information regarding the influence of higher education ($p < .001$) and completion of an accredited educational program ($p = .007$) upon critical thinking skills. The results of this study support the direction of the education of future medical dosimetrists. In 2017, the education requirement for MDCB certification will be set to a minimum of a Bachelor's degree and completion of a JRCERT accredited educational program.

This research also opens the discussion of the critical thinking skills decreasing with experience. The significant negative correlation ($r = -.23$, $p = .012$, $d = .27$) is in need of further research with a larger sample size. A longitudinal study testing a sample at more points along the learning spectrum or with appropriate continuing education may return more meaningful results in the population of medical dosimetrists with long-term effects.

This study supports the trend of more education and accreditation of educational programs to enhance and develop critical thinking skills. The negative correlation between experience and critical thinking skills, though, may be explained by looking at the background of the two samples. Sixty-five percent of the professional sample had a minimum of a Bachelor's degree, while 87% of the student sample had a minimum of a Bachelor's degree.

Eighty-eight percent of the professional sample compared to 61% of the student sample were trained or previously practiced as an RTT, basically trained as technicians. Eighty percent of the professional sample never attended an accredited program and about half of the sample was trained on-the-job in a variety of clinical environments, with a majority in community hospitals and freestanding centers. All of the students are currently attending a formal educational program, with only 5% attending a non-accredited program. The results of this study revealed that less education, previously being trained as an RTT, and not graduating from an accredited program were all indicators of an individual with weaker critical thinking skills.

Many authors have attempted to shed some light on how individuals reason (Tversky, A. & Kahneman, D.,1981, 1983, Kahneman, D. & Tversky, A.,1984, Cohen, M, Freman, J. & Wolf, S.,1996, King, A., 2002, 2011, Kamhi, A., 1999, 2011, Finn, P., 2011, Besnard D. & Bastien-Toniazzo, M., 1999, Ferrario, C., 2003, Wainright, S., et al, 2011). Tversky & Kahneman (1981) present the approach that decisional outcomes are based on probability of certainty and the framework of the question. Novices and experts have varying degrees of certainty when making clinical decisions. Each group might approach a situation with a different frame of reference. They both have the clinical knowledge and skills, but experts have experiential knowledge, which frames their decisions.

Cohen's (1996) model of metarecognition explains that sometimes

decision makers need time to think about a problem before making a decision, because the conclusion is not obvious or there is lack of evidence. One could hypothesize that novices spend more time considering all of the evidence and looking for relationships before making a decision. Experts are familiar with protocols and therefore maybe quick to fit the clinical situation into a class solution or protocol.

A qualitative study by Wainwright, et al (2011), identified factors that influence clinical decision making of novice and experienced physical therapists. The authors reported that novices used informative factors; academic content and faculty mentorship, theories, and anticipated patient performance. Experts used more directive factors; information in the medical record, observation of the patient's abilities, and observation of the patient's behavior.

The novice might rely on hypothetical possibilities, while the expert might tend toward heuristic possibilities, meaning those based on their experience. The novice might spend more time considering the alternatives to their decisions; while experts will try to "fit" the situation into a "box" they have seen before. While all of these might explain the negative correlation, a deeper dive into this topic may reveal more about this phenomenon in this profession.

In summary, this study reported on the critical thinking skills of medical dosimetry students and professionals and provided some meaningful support

for the 2017 certification initiative for a minimum educational requirements and support for accreditation of educational programs. This study also revealed a significant difference between students and practicing professionals with regard to their inference skills. Further exploration of the factor of experience would contribute to a better understanding of critical thinking skills through the journey from novice to expert in this population. Studies about certification, education, and experience have many possibilities for research in this population.

Limitations

This study attempted to describe a group of very unique health science professionals and students, but it is not generalizable to the entire population of medical dosimetrists practicing in the United States. The sample represented only about 10% of the entire population. The total size of sample group and subgroups of professionals and students met the minimum required number of subjects based on *a priori* power analysis.

Lack of test taker effort or cognitive fatigue may have contributed to twenty percent of the sample having not completed the minimum number of test questions on the HSRT (60%), as required by Insight Assessment. The HSRT is comprised of 33 test items and takes about 60 minutes to complete. Each item is a vignette of a situation phrased in a clinical setting. The test taker must read each item carefully and then choose from a list of multiple-choice answers. It is recognized that lack of test taker effort and cognitive

fatigue may have contributed to eliminating about 20% of the group for analysis.

While Insight Assessment reports statistically similar results with the paper and electronic versions of the HSRT, this study utilized two different distribution methods for each version. Paper surveys were distributed only to entry-level students through the office of their program director and the electronic version was distributed to the general medical dosimetry population through an email solicitation letter sent by the AAMD. The benefit of distributing the paper surveys to students through the office of the program director resulted in a very high return rate (64%), however the surveys were slow to return to the principal investigator and the principal investigator was required to forward the completed surveys to Insight Assessment for analysis. The electronic distribution method resulted in a low return rate (12.4%), however the surveys were directly linked to Insight Assessment and results were available in a timely fashion. The results of the demographic survey are based on self-reported data.

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Appendix A

Pilot Study

Purpose.

The three purposes of the pilot study were (1) explore critical thinking skills of entry-level medical dosimetry students enrolled in a formal medical dosimetry educational program, using the Health Sciences Reasoning Test (HSRT), (2) explore if a relationship existed between critical thinking skills and educational degree, and (3) explore if a relationship existed between critical thinking skills and years of healthcare experience.

Methods.

I identified the formal medical dosimetry educational programs in the United States and contacted the program directors for permission to solicit voluntary participation of their students. I developed a demographic survey, which included the independent variables for the study were age, gender, ethnicity, educational degree, radiation therapist (RTT) status, geographic region, and year's experience in healthcare and medical dosimetry, and type of prior healthcare experience. Since the paper version of the HSRT was only available in English, I included a question to determine if the subject was bilingual and what is his/her primary language. On open-ended questions was added, "Why did you enroll in a formal medical dosimetry educational program?"

The dependent variables were the total HSRT score and five sub-scale

scores; deductive, inductive, analysis, inference, and evaluation. A description of the tool is given in the body of the paper.

The paper version of the HSRT was used to determine critical thinking skills. The HSRT is distributed by Insight Assessment, Inc. and designed to test critical thinking skills of health science students and professionals. It is a multiple-choice test with 33 items pooled from the California Critical Thinking Skills Test (CCTST), but framed in a health science context. The results of the test are returned with the total score and sub-scores in each of five critical thinking categories; deductive, inductive, analysis, inference, and evaluation.

The sample included all males and females, 18 years old or older and entry-level medical dosimetry students enrolled in a formal medical dosimetry educational program. Subjects excluded from the study include those who are less than 18 years old, are students enrolled in other formal educational programs other than medical dosimetry, and medical dosimetrists enrolled in a clinical "on-the-job" training program.

Formal medical dosimetry educational programs in the United States were identified and program directors were contacted. After Seton Hall University Investigational Review Board approval, the survey packets, which included a demographic survey and the paper version of the HSRT, were assembled and mailed to program directors of formal medical dosimetry educational programs, who agreed to allow their students to participate. The program secretary, or designated research assistant, distributed the packets

to the students and collected the completed packets. The packets were returned to the principal investigator by mail.

Results and Discussion.

The target population were students in the 21 medical dosimetry programs in the United States, which included accredited programs under review for accreditation, and non-accredited programs. While the capacity for these programs was about 165, only 132 students were currently enrolled in the programs. The accessible population included those students whose program director's agreed to distribute the survey packets. Sixteen programs participated, with an enrollment of 89 students. Fifty-seven students returned the packets, which was 64% of the accessible population and 43.2% of the target population. For analysis purposes, only 56 students completed the demographic survey and 56 students completed the HSRT. One HSRT score was eliminated because the subject answered less than 60% of the questions; therefore only 55 HSRT tests were available for analysis and 54 subjects available for full analysis.

The mean age of sample was 25 and although over 20% of the sample did not respond to the question on gender, the sample was equally divided between male and female. Ninety percent of the sample had a minimum of a Bachelor's degree and 10% had less than a Bachelor's degree.

The majority of the student sample had less than 5 years experience in clinical healthcare, 41% had 3-5 years experience and 25% had no prior

healthcare experience. Only 16% of the sample had prior experience in medical dosimetry. About 60% of the sample were trained or practiced as a radiation therapist (RTT) prior to enrolling in the medical dosimetry program.

The sample mean total HSRT score was 21.6, which was in the strong region of critical thinking. The median score was 22 and the mode was 20. Central tendency was confirmed for the total scores, well as all five sub-scale scores for the group. The mean sample score for deductive reasoning was 6.4 and the mean sample score for inductive reasoning was 7.8. The mean sample score for the analysis was 4.4, inference was 3.2, and evaluation was 5.1.

According to Insight Assessment, Inc., the total HSRT score is the strongest indicator of critical thinking skills (Facione, 2013). The total mean score of the sample was 21.6 and this score is consistent with individuals who have strong critical thinking skills necessary for academic success and career development. A study by Lowy (2012), reported that physician assistant students had a mean score of 20.2 and a study by Huhn, et al (2012) reported that physical therapy novices had a mean score of 22.5. The total HSRT mean score was significantly higher than the PA students ($p = .008$), but not significantly lower than PT novices ($p = .053$). Since 90% of my sample reported that they are college graduates, I compared the sample mean to the national norm (50th percentile) for all 4-year college graduates, which is 19.4 and all health science graduates, which was 20.0. The sample mean was

significantly higher than both groups; all 4-year college graduates (p < .001) and all health science graduates (p = .003).

The second purpose of the pilot study was to compare the critical thinking skills of the entry-level students with their level of education. The groups were not evenly divided and only 5 students had less than a Bachelor's degree, therefore the Mann-Whitney U test was used to compare the total HSRT scores and all 5 sub-scale scores of the two groups. The difference between the mean scores of the two groups was not significant for the total HSRT, nor for the sub-scores for deductive, inductive, analysis, and evaluation. The only significant difference between the two groups was in the inference sub-scale score (p = .004).

The subjects were divided into two sub-groups; those who were trained and/or practiced as an RTT prior to enrolling in the medical dosimetry educational program and those who were not trained or who practiced as an RTT. The mean of the group who was not trained or practiced as an RTT was higher than the mean of the group that practice and/or trained as an RTT. The difference between the groups was significant for the total HSRT score (p = .025) and the deductive sub-scale score (p = .026), but not significant for any of the other sub-scale scores.

The relationship between the total HSRT score and the years of clinical healthcare experience of the sample showed a significant negative correlation (r = -.305, p < .001). Similar results were found for the inductive, deductive

and inference sub-scale scores. No statistical correlation was found for the analysis and evaluation sub-scores. No significant correlation was found between the total HSRT score or any of the sub-scale scores and the year's experience of clinical medical dosimetry experience.

Eighteen students reported that they are bilingual, but only 7 students reported that English is not their primary language.

The last question was qualitative and asked the subjects why they enrolled in a medical dosimetry educational program. Several themes emerged from their responses. Approximately, twenty percent of the students who chose to answer this question were interested in furthering their education and obtaining certification, while approximately 13% stated that they desired to attend an accredited training program and obtain a job in a secure profession.

Summary and Conclusions.

The limitations of the pilot study included that no all students were accessible for the study, as not all program directors agreed to distribute the packets. Since only those students who elected to complete the survey did so, the pilot study was a sample of convenience. The sample size was 57, but only 54 were available for correlation studies and when the sample was divided into sub-groups, the size of some groups was small and/or did not meet the criteria for normality and therefore nonparametric statistics could not be employed for all analyses. The distribution of the paper version was

tedious and expensive. An electronic version would for an easier and more efficient method of distribution and collection of data. Lastly, the students were surveyed at only one point in time, at the beginning of their educational program.

The pilot study supported the use of the HSRT as an appropriate tool to measure critical thinking skills of medical dosimetrists. It provided insight into the critical thinking skills of entry-level medical dosimetry students enrolled in a formal educational program and supported the continuation of research of medical dosimetrists across the learning spectrum.

While the pilot showed an upward trend in critical thinking skills with education, a larger sample size will strengthen the statistics. A larger and more diverse sample will also increase the statistics in the correlation between critical thinking skills and experience. The pilot showed a significantly weak negative correlation between critical thinking and healthcare experience and no significant relationship between critical thinking and Medical Dosimetry experience. This finding is contrary to research reported by Ingram (2008), who found no significant correlation between critical thinking skills and experience in nurses.

Medical dosimetry is a small group of relatively new health science professionals and the profession is expected to grow to meet the need to treat cancer patients with radiation. The medical dosimetrist is a crucial member of the radiation team and makes clinical decisions that require critical thinking

skills. They actively interpret the physician's intent for treatment, analyze the unique situation of the patient and their disease, develop a unique radiation treatment plan that accurately target the tumor, and effectively communicate the plan to the therapist, who safely delivers the radiation dose. Further research will provide meaningful data by describing critical thinking skills of this small, but highly technical and very unique profession.

Appendix B

Seton Hall University Investigational Review Board Approval

July 10, 2012

Anne Greener
18 Chestnut St.
Chatham, NJ 07928

Dear Ms. Greener,

The Seton Hall University Institutional Review Board has reviewed the information you have submitted addressing the concerns for your proposal entitled "Critical Thinking Skills and Education of Medical Dosimetry Students and Professionals." Your research protocol is hereby approved as revised through exempt review. The IRB reserves the right to recall the proposal at any time for full review.

Please note that, <u>where applicable</u>, subjects must sign and must be given a copy of the Seton Hall University current stamped Letter of Solicitation or Consent Form before the subjects' participation. All data, as well as the investigator's copies of the signed Consent Forms, must be retained by the principal investigator for a period of at least three years following the termination of the project.

Should you wish to make changes to the IRB approved procedures, the following materials must be submitted for IRB review and be approved by the IRB prior to being instituted:

- Description of proposed revisions;
- *If applicable,* any new or revised materials, such as recruitment fliers, letters to subjects, or consent documents; and
- *If applicable,* updated letters of approval from cooperating institutions and IRBs.

At the present time, there is no need for further action on your part with the IRB.

In harmony with federal regulations, none of the investigators or research staff involved in the study took part in the final decision.

Sincerely,

Mary F. Ruzicka, Ph.D.
Professor
Director, Institutional Review Board

cc: Dr. Genevieve Pinto Zipp

Appendix C

Solicitation Letter

SETON HALL ⛪ UNIVERSITY™

1 8 5 6

Medical Dosimetry Students and Professionals Needed

My name is Anne Greener and I am a clinical Medical Physicist. I am also a doctoral student at Seton Hall University, South Orange, New Jersey and am looking for Medical Dosimetry students and professionals to participate in a study. If you are a student in a Medical Dosimetry program or a practicing professional, you are eligible to participate.

During the study, we will be asking Dosimetry students and professionals to anonymously complete a survey that will provide information on your critical thinking skills. Included is a short demographic survey. We ask that you complete the survey on-line and it will take no more than 60 minutes of your time.

Participation in this study is completely on a volunteer basis and you can decide not to participate. All data will be kept confidential and kept on a password-protected USB drive in a locked file cabinet with access provided only to the primary researcher and research assistant. All information will be kept for a minimum of three years and then shredded.

If you would like to volunteer to participate in this study, please click on the link provided in the email and you will be sent directly to the on-line survey. When you reach the site, please read the direction carefully and use the username and password provided to you in the email to access the survey.

Thank you for your participation in this study.

For more information on participation in this study, please contact the primary investigator:

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18 Chestnut St.
Chatham, New Jersey 07928
201-788-1401
anne.greener@student.shu.edu

Seton Hall University
Institutional Review Board

JUL 1 0 2012 .

Approval Date

A   H O M E   F O R   T H E   M I N D ,   T H E   H E A R T   A N D   T H E   S P I R I T