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Teaching And Assessing Critical Thinking In Radiologic Technology Students

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TEACHING AND ASSESSING CRITICAL THINKING IN RADIOLOGIC TECHNOLOGY STUDENTS

by

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ABSTRACT

The purpose of this study was primarily to explore the conceptualization of critical thinking development in radiologic science students by radiography program directors. Seven research questions framed three overriding themes including 1) perceived definition of and skills associated with critical thinking; 2) effectiveness and utilization of teaching strategies for the development of critical thinking; and 3) appropriateness and utilization of specific assessment measures for documenting critical thinking development.

The population for this study included program directors for all JRCERT accredited radiography programs in the United States. Questionnaires were distributed via Survey Monkey©, a commercial on-line survey tool to 620 programs. A forty-seven percent (n = 295) response rate was achieved and included good representation from each of the three recognized program levels (AS, BS and certificate).

Statistical analyses performed on the collected data included descriptive analyses (median, mean and standard deviation) to ascertain overall perceptions of the definition of critical thinking; levels of agreement regarding the effectiveness of listed teaching strategies and assessment measures; and the degree of utilization of the same teaching strategies and assessment measures. Chi squared analyses were conducted to identify differences within each of these themes between various program levels and/or between program directors with various levels of educational preparation as defined by the highest degree earned.

Results showed that program directors had a broad and somewhat ambiguous perception of the definition of critical thinking, which included many related cognitive processes that were

not always classified as attributes of critical thinking according to the literature, but were consistent with definitions and attributes identified as critical thinking by other allied health professions. These common attributes included creative thinking, decision making, problem solving and clinical reasoning as well as other high-order thinking activities such as reflection, judging and reasoning deductively and inductively. Statistically significant differences were identified for some items based on program level and for one item based on program director highest degree.

There was general agreement regarding the appropriateness of specific teaching strategies also supported by the literature with the exception of on-line discussions and portfolios. The most highly used teaching strategies reported were not completely congruent with the literature and included traditional lectures with in-class discussions and high-order multiple choice test items. Significant differences between program levels were identified for only two items.

The most highly used assessment measures included clinical competency results, employer surveys, image critique performance, specific course assignments, student surveys and ARRT exam results. Only one variable showed significant differences between programs at various academic levels.

This dissertation is dedicated to my family whose support helped me persevere when I was overwhelmed, whose encouragement motivated me when I was disheartened and whose love continually reminded me what is truly important in life.

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CHAPTER ONE: INTRODUCTION

Background

Radiologic science is a relatively young field transitioning between classification as a vocation or trade to that of a profession in its own right. While the field meets many of the criteria applied toward professionalization, one fundamental omission is that individuals in the field practice autonomously and have authority over independent decision making (Tilson, 2005). Autonomous, independent decision making requires both the skills and dispositions to think critically (Francis, 2008). In 2005, the *American Society of Radiologic Technologists* (ASRT) established the *Health Care Industry Advisory Council* (HCIAC) to determine what steps must be taken to ensure that radiologic technologists are properly educated and prepared for the rapid and complex changes taking place within the profession. This panel concludes that educators must instill a commitment to life-long learning and continued adaptation to new technologies and procedures (Martino & Odle, 2006); these attributes are only attainable via these self-same characteristics of professional autonomy and self-directed decision making.

Critical thinking is fundamental to the achievement of many goals expressed by those in the radiologic sciences as well as other allied health professions. These goals are related to improvement in patient care outcomes and health care reform efforts and can only be attained through the use of reasoning and problem solving skills, critical reflection, and professionalization of the radiologic sciences. Radiologic technology is a medical specialty which encompasses a myriad of procedures in which images are produced for diagnosis and treatment of pathological conditions. Radiographers are tasked with administering controlled doses of ionizing radiation in order to produce high quality, diagnostic images. This must be accomplished while providing patient care during the performance of often complex diagnostic procedures on unfamiliar patients whose status may change rapidly.

In the mid-1990's radiology executives were surveyed by their professional organization, the *American Healthcare Radiology Administrators* (AHRA) which confirmed that the need for critical thinking in diagnostic imaging was indeed increasing, yet graduates of educational programs were ill prepared to demonstrate critical thinking on the job. These survey results led to the beginning of new conversations within the profession and important revisions in educational standards and curricula to include critical thinking and problem solving as key educational goals (Bugg, 1997; Stadt & Ruhland, 1995).

More recently, healthcare executives cited adapting to new technology, increasing patient safety and reducing medical errors as some of their top business concerns (Martino & Odle, 2006). Unfortunately, significant barriers to applied critical thinking persist throughout the imaging world, as much of radiographic practice was and continues to be protocol driven. This contributes to a work culture in which critical thinking is actually discouraged by many department managers and physicians even though it is verbally reinforced as a needed skill. This dilemma is one which will need to be addressed by professionals and educators because blind adherence to protocol may be an important contributor to medical errors and patient injury.

Significance of the Problem

As a major goal of all levels of education including higher education in medicine and the allied health professions, critical thinking is a highly valued and sought after characteristic. This is because of its role in clinical judgment and reflection which encourages questioning the status quo to allow for positive changes in previously unquestioned practices (Bugg, 1997; Mundy & Denham, 2008; O'Dell, Mai, Thiele, Priest, & Salamon, 2009; Sim & Radloff, 2009; Sim, Zadnik, & Radloff, 2003; Yielder & Davis, 2009). Defined by critical thinking experts as an essential tool of inquiry which combines cognitive skills and affective dispositions (P. A. Facione, 1990), the concept remains quite vague when making direct application to professional clinical practice.

In the medical sciences, most professionals have a tendency to approach their disciplines in a manner in which there is always a "best" course of action and the task is to uncover and consider all the relevant information to use in making sound decisions; thus choosing actions appropriately. Is this what radiologic technologists mean when discussing critical thinking? Or is it more than this? Experts identified during Facione's Delphi study state that critical thinking is "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based" (P. A. Facione, 1990, p. 2). Within today's healthcare environment, it is imperative that health care professionals possess the ability to think critically in order to provide optimum patient care during diagnosis and treatment of complex acute and chronic illnesses among an increasingly diverse patient population (Bugg, 1997; Leaver & Norris, 1999; Mundy & Denham, 2008; O'Dell et al., 2009).

In establishing a consensus regarding how to best develop these abilities, the definition of critical thinking is gradually being transformed across various applications and disciplines (Gordon, 2000; Mundy & Denham, 2008; Scheffer & Rubenfeld, 2000; Staib, 2003; Zakus, Malloy, & Edwards, 2007). While the debate continues as to whether true critical thinking is a generalizable or discipline specific skill; or a combination of the two (Stone, Davidson, Evans, & Hansen, 2001), the purpose of this study will be to consider the discipline specific applications only.

Problem Statement

Critical thinking has been the topic of many research studies within nursing and other allied health professions over the past two decades. While much has been discovered, there remain many gaps in knowledge and understanding of how this trait develops and is exhibited by students and practitioners (Gordon, 2000; Mundy & Denham, 2008; Staib, 2003). Within radiologic technology, there has been little empirical research conducted to date; none of which addresses a working definition of this construct. Critical thinking is included as a required learning outcome by many accrediting agencies (N. C. Facione & Facione, 2008), including the *Joint Review Committee on Education in Radiologic Technology* (JRCERT) and is addressed in the *Standards for Educational Programs* (Aaron & Haynes, 2005; Joint Review Committee on Education in Radiologic Technology, 2008), and published curriculum guides used by all recognized programs as well as professional practice standards (American Society of Radiologic Technologists, 2007). The conundrum then is that while educators recognize the need to teach critical thinking, exactly what this looks like in diagnostic imaging professionals has never been identified. Therefore it is not known whether educators are effectively developing it in students. It is imperative to assess current practices and establish a standardized measure to be used for future assessment. "The process of developing a good educational assessment tool of any kind begins with the construct or idea that one seeks to measure. The construct validity of the instrument depends on how well an idea has been articulated and how well the tool captures that idea" (P. A. Facione, Facione, & Giancarlo, 2000, p. 12).

In nursing, critical thinking is evaluated differently by various educational programs based on the accepted definition applied by each (Videbeck, 1997). The same is likely true in radiologic sciences. Therefore, educators must first come to a collective agreement; understand what critical thinking looks like in professional radiographers and then subsequently develop appropriate teaching strategies and assessment measures.

Because there is no foundation upon which to build a collective understanding regarding the development and assessment of critical thinking, it will be necessary to address more than one issue in this and future studies. The conversation must be renewed among radiologic sciences educators and professionals in order that some consensus can be reached regarding what critical thinking looks like in diagnostic imaging, how to best develop this attribute in students, and devise effective and reliable assessment tools to monitor progress. This study will benefit the field of radiologic technology by identifying what is needed to enhance the effectiveness of critical thinking development in its students.

Purpose Statement

Entry level radiologic sciences programs in the United States are taught at one of three academic levels: the certificate or hospital-based diploma level, the Associate of Science (AS) degree offered at community colleges, and the Bachelor of Science (BS) degree sponsored by universities. All three are accredited by the JRCERT based on identical standards and outcomes measures. The certificate and AS programs use a common curriculum guide while the BS level is designed using an enhanced curriculum guide which expands on the core content areas and learning objectives (ASRT, 2007; JRCERT, 2008). The literature shows there may be some evidence that allied health and nursing students in BS programs exhibit higher levels of critical thinking than those in educational programs at lower levels, and that educators with more advanced degrees have a deeper understanding of the construct and appropriate teaching strategies for developing critical thinking in students (Fero, Witsberger, Wesmiller, Zullo, & Hoffman, 2009; Leaver & Norris, 1999; Shin, Jung, Shin, & Kim, 2006).

The intent of this research therefore is to first determine how radiologic sciences educators define critical thinking, and identify current teaching and assessment strategies used within educational programs; and then identify any differences seen in programs taught at different academic levels and by faculty with varying levels of academic preparation. By developing and administering a survey instrument to program directors of accredited, entry-level radiography programs, data were collected and evaluated to identify areas of consensus and dissonance to establish a baseline for use in subsequent studies and for comparison to work done across the other medical disciplines.

Research questions and hypotheses

The following research questions and hypotheses were addressed in this study.

1. How is critical thinking currently defined by radiologic sciences program directors?
2. How do radiologic science programs teach critical thinking?
3. How do radiologic science programs assess critical thinking?
4. Are there differences in the definition or perceived skills associated with critical thinking between programs taught at different levels (BS, AS and certificate)?

   $H_Ø$4.1 There are no differences in the definition or perceived skills associated with critical thinking between BS, AS and certificate level programs.

5. Are there differences in the definition or perceived skills associated with critical thinking among program directors with varying levels of academic preparation?

   $H_Ø$5.1 There are no differences in the definition or perceived skills associated with critical thinking between program directors with masters versus doctoral degrees.

6. Are there differences in reported critical thinking teaching strategies between programs at various educational levels (BS, AS and certificate)?

$H_Ø6.1$ There are no differences in reported critical thinking teaching strategies between BS, AS and certificate level programs.

7. Are there differences in reported critical thinking assessment measures between programs at various educational levels (BS, AS and certificate)?

$H_Ø7.1$ There are no differences in reported critical thinking assessment measures between BS, AS and certificate level programs.

Methods

This quantitative research study is both descriptive and exploratory. Data were collected through the administration of a questionnaire using the commercial survey tool, Survey Monkey®. This survey was distributed to all JRCERT accredited radiography programs in the United States. The instrument solicited information regarding the perceived definition of, and the skills associated with critical thinking by the participants; reported teaching strategies and assessment methods; and reported programmatic learning outcome measures. These data were subsequently analyzed with SPSS using both descriptive and inferential statistics to determine how critical thinking is currently defined, taught and assessed in radiologic sciences educational programs.

Significance of Study Results

The results of this study will help to establish a foundation for the radiologic technology profession and educational programs regarding the definition, teaching and assessing of critical thinking. Identification of current teaching strategies and assessment methods will lead to renewed conversation among educators and the subsequent development of a valid construct for critical thinking within this field, allowing for future study and improvement in theoretically sound and effective teaching methods. This in turn should pave the way for future studies in which standardized measures for critical thinking can be assessed among populations at different professional levels and thus help align efforts with those in progress in nursing and other related allied health professions.

Assumptions and Delimitations

This study did not attempt to assess the appropriateness or the effectiveness of the methods and measures identified; rather it merely reports on current perceptions and the level of understanding among radiography educators as well as specific critical thinking measures reported to JRCERT. It was assumed that participants had access to email and internet connections by which to receive communication from the researcher and complete the survey tool. Most significant was the assumption that radiography education and professional practice are similar enough to other allied health professions that it was appropriate to use those literature bases and research results to serve as a foundation for radiologic sciences. Identified perceptions and definitions of critical thinking among radiologic sciences educators were evaluated based on previously determined definitions within these professions (Gordon, 1995) to show whether past research results in nursing and other allied health fields might have validity to inform radiologic sciences based on this supposition; that critical thinking skills and dispositions needed for making sound clinical decisions are similar for these professions.

Limitations

The limitations of this study included the research design in which only program directors were solicited for input, thus neglecting the contribution of other faculty. Because only JRCERT recognized programs were included, the study did not consider the perceptions of those accredited by other organizations. There was significant imbalance in the population sizes. Based on the response rate of each of the sub-populations, some results exhibited lower statistical power. While the entire populations within each stratum were invited to participate, conclusions were drawn from data collected from those who chose to respond rather than the entire population, and since there are likely to be differences in the inherent characteristics of respondents versus non-respondents, generalizability may not be assured. There remains the fact that not all programs were included and therefore, the results obtained may not be true of all radiography programs. In addition, potential bias of the researcher and the lack of a framework upon which to structure this study limit the assertion of validity and reliability.

Definition of Terms

Accredited Educational Program – entry level programs in radiologic science which are recognized by the JRCERT. These must meet published standards to provide students with appropriate didactic and clinical experiences to ensure their eligibility to take the

ARRT certification exam and prepare them for professional practice. Entry level programs are taught at the following three levels:

Hospital-based certificate program – may be sponsored by a healthcare organization or academic institution. These are two year programs based on satisfactory completion of didactic instruction designed to complement clinical experience and may be more grounded in the apprenticeship model of education (ASRT, 2007).

Associate of Science degree – two year degree considered to be vocational in nature with limited general education requirements (ASRT, 2007).

Bachelor of Science degree – considered the professional level by the ASRT; consists of four years of academic study with complete general education curriculum in addition to the radiologic sciences core course and clinical experience (ASRT, 2007).

American Registry of Radiologic Technologists (ARRT) – national agency providing professional oversight and credentialing of imaging personnel; establishes certification eligibility criteria for each of the primary and post-primary imaging modalities (ASRT, 2007).

American Society of Radiologic Technologists (ASRT) Radiography Curriculum Guide – a blueprint for program design which supports the development of instruction and practical clinical experiences centered on specific imaging technologies to prepare graduates with essential clinical skills and the knowledge base to take the certification exam offered by the ARRT (ASRT, 2007).

American Society of Radiologic Technologists (ASRT) BSRS Core Curriculum Guide – enhances the entry-level curriculum guide to expand content areas and support post-primary certifications and transition to advanced education and clinical practice for students enrolled in a Bachelor of Science degree program.

Clinical Education – the practical component of the educational program during which the student practices performing procedures on real patients in a community based healthcare facility such as a hospital or outpatient imaging center.

Joint Review Committee on Education in Radiologic Technology (JRCERT) - national agency responsible for setting and enforcing standards for the accreditation of educational programs in medical imaging

Laboratory Course – practical, hands-on aspect of didactic courses which complements course content and provides opportunities for students to practice psychomotor skills and decision making in a simulated environment prior to clinical internships

Practice Standards – developed by the ASRT and define the parameters of professional practice and establish general criteria for appropriate performance of general duties. These are used to judge the appropriateness and quality of an individual's professional practice.

Radiologic Technology – medical specialty involving the diagnosis and treatment of pathological conditions through the safe and effective application of ionizing and non-ionizing radiations Synonyms: diagnostic imaging, medical imaging, radiologic sciences (ASRT, 2007).

Radiographer – allied health professional responsible for safely administering ionizing radiation during the production of diagnostic medical images (ASRT, 2007).

Summary

As a required programmatic outcome for recognition by the JRCERT, critical thinking must be defined for application to the radiologic sciences before it can be determined whether current teaching strategies are effective and before appropriate assessment measures can be developed. The data collected and analyzed through this research study will establish a foundation for renewed conversation among radiography educators and provide a baseline for comparison of works in critical thinking for radiologic sciences to those in progress across nursing and the other allied health professions. By building on the work of colleagues in related health professions, radiologic sciences educators can more quickly and effectively address vital issues within the imaging professions; and assure that graduates of educational programs are supplied with the tools they need to engage in critical and reflective thinking during problem solving; improve patient care by minimizing the probability of life threatening errors; and elevate the field to more accurately reflect its complexity.

CHAPTER TWO: LITERATURE REVIEW

A search for relevant literature was conducted using the databases of *ERIC, CINAHL, Pubmed, Ebscohost* and *Dissertation & Theses*. A search of *Radiologic Science and Education* was conducted separately as this journal is not included in any of the standard databases. Various combinations of key search terms were used and included: critical thinking, deep thinking and effective thinking as well as the associated constructs: clinical reasoning, clinical judgment, decision making and problem solving. Applicable literature was included from radiologic sciences as well as related clinical professions such as medicine, nursing, physical therapy, athletic training and respiratory therapy. General applications of critical thinking from post-secondary education literature were also included.

Critical Thinking in Higher Education

Theoretical Perspective

A common criticism of schools verbalized by William Graham Sumner more than 100 years ago in 1906; that our educational system, by design, produces "men and women all of one pattern, as if turned in a lathe" (Paul, Elder, & Bartell, 1997, p. 3), is still a concern today. This tendency remains the root of many of our current deficiencies wherein students, each from unique backgrounds and with diverse educational needs, are ill served by a system seeking conformity and standardization. Sumner believed and wrote that if a society existed wherein critical thinking was a major societal value, every dimension of life would be transformed (Paul et al., 1997). The purpose of true education then must be to produce citizens with well-developed critical minds. For this to occur, students must develop the habit of critically analyzing information and concepts, assessing them for accuracy, truth, relevance, depth, extent and logic. Critical thinking is often touted as the cure-all for our educational woes. It is promised that critical thinkers are destined to become successful performers of complex tasks requiring astute problem solving; rather than passive recipients of vast stores of knowledge. The ultimate goal of education then, to strike a balance between theory and practice, will be accomplished when critical thinking skills are effectively learned and transferred to different domains (P. A. Facione, Giancarlo, & Gainen, 1995; Papastephanou & Angeli, 2007).

Critical thinking as a method of teaching and learning requires students to be self-monitors and self-assessors. Students, however, socialized through at least 12 years of passive learning in our public schools are often very uncomfortable and resistant to making the intellectual effort required for critical thinking (Mason, 2007; Tsui, 2002). Through constant reinforcement, students have come to prefer this system of passively listening to a lecture and rote memorization of facts. They have been deceived into thinking (just as teachers have also been deceived) that learning is taking place when in fact little of what is covered in class is retained.

Critical thinking is described as a desirable cognitive trait by almost all undergraduate and graduate level academic institutions. The academic culture of higher education today embraces this notion of critical thinking as perhaps the most vital skill a graduate should attain during his or her schooling (Lampert, 2007; Paul, 2004). Defined by contemporary scholars as “reflective thinking focused on the evaluation of various alternatives” (Lampert, 2007, p. 17), critical thinking engages individuals in reflective thinking when presented with problematic situations in any discipline; moving beyond personal bias to consider other viewpoints and good evidence (Papastephanou, 2007, citing Giancarlo & Facione).

Multiple studies cited by Richard Paul (2004) indicate that college and university faculty overwhelmingly affirms that critical thinking is indeed a primary goal of higher education and of prime importance in their personal instructional techniques. Unfortunately, very few of these same faculty are able to explain what critical thinking entails or to describe their strategies for covering content while fostering critical thinking in the classroom. College faculty often do not use critical thinking as the basis for teaching strategies because they do not really understand what it is. They may teach content without the essential thinking skills necessary to effectively master it. For example they teach science concepts without teaching how to think scientifically. Even in the realm of mathematic problem solving, students are taught to apply a pre-determined and rehearsed set of mechanistic steps to arrive at the correct answer rather than how to think (Paul, 2004). Many teachers simply do not comprehend the vital role that thinking plays in understanding content. This lack of understanding translates into teaching strategies which are counterproductive for enabling students to become skilled thinkers (Paul, 2004; Tsui, 2002).

This lack of understanding of what critical thinking is and how it is fostered is directly manifested by stubborn adherence to outdated and ineffective teaching strategies in which vast quantities of factual information is presented to passive students during a formal lecture. Students are expected to commit this content to memory and accurately regurgitate it on a written exam. Many, in effect simply teach students to master their short-term memory and test taking skills; neither of which will enable them to make substantive contributions to their professions or society. Research suggests that indeed, rarely is critical thinking occurring in college classrooms, however, it can be cultivated through instruction designed to lead students to actively engage with the content. Learning becomes more meaningful and perhaps even easier when students comprehend the logic and sense of what they are learning. Regardless of the discipline, content can and should be presented as a mode of thinking. Knowledge is constructed by the student through careful organization, evaluation and analysis of concepts (Papastephanou & Angeli, 2007; Paul, 2004; Tsui, 2002).

Historical Perspective

Critical thinking as a curriculum dates back almost to the beginning of recorded history to the time of the ancient Greek philosophers. Socrates proposed a form of reasoning that required clear and consistently logical thinking. He recognized the importance of reason in thinking; including seeking substantiated facts, closely probing assumptions, analyzing fundamental concepts, and tracing out the implications of what is said as well as what is done (Paul, Elder, & Bartell, 1997; Tanenbaum, Tilson, Cross, Rodgers, & Dowd, 1997). These early educators and philosophers emphasized that systematic thinking is required to seek out the "deeper realities of life" since things often appear to be different than they actually are. This teaching strategy referred to as Socratic questioning is still one of the most recognized methods for teaching critical thinking (Tanenbaum et al., 1997).

Robert Ennis is often cited as the initiator of renewed academic interest in critical thinking with his 1962 article entitled, *A Concept for Critical Thinking*. At that time, his definition of critical thinking, which is still widely cited today, was “reasonable, reflective thinking that is focused on deciding what to believe or do” (Ennis, 2002; Pinar, Reynolds, Slattery, & Taubman, 1995, p. 773). Ennis initiated the discussion and emphasized skills in the assessment of critical thinking, and developed a list of abilities and dispositions to be used in testing critical thinking skills (Fasko, 2003)

Before long, other prominent philosophers began to add to the discourse. Critical thinking theorists propose abstract definitions which appear on the surface to be quite similar, however differences become more apparent within the language used to construe a more concrete definition, and learning activities relevant to developing this ability (Gilliland, 2006). In their attempt to clarify and conceptualize critical thinking, Bailin, et al. (1999) posit that a more tangible definition must be developed; one that corresponds to the basic concept that educators in the field have. They expound on an essential concept concerning the types of judgments that qualify as critical thinking; the nature of standards applied to critical thinking; the nature of activities that constitute critical thinking; and the procedures or operations that are used to meet those standards (Bailin, Case, Coombs, & Daniels, 1999). Unfortunately their lengthy explanation does little to expand our understanding; rather it merely introduces even more complex vagaries.

In comparing critical thinking to creative thinking, problem solving and decision-making many authors take a slightly different course than theorists who would argue that each is a distinctly different activity. In contrast, they state that these activities all utilize various processes that are interrelated and require critical thinking to carry out effectively. In other words, critical thinking requires creativity and problem solving skills (Bailin et al., 1999). As a provocative addition to current theory, Bailin, et al. (1999) avoid listing specific skills or attitudes needed to be an effective critical thinker, stating that such lists simply distract educators by encouraging them to see developing critical thinking as “simply a matter of teaching students a new and discrete skill” (p. 290). Instead they identify and expand on five intellectual resources critical thinkers consistently utilize, including: “background knowledge, operational knowledge of the standards of good thinking, knowledge of key critical concepts, heuristics (strategies, procedures, etc), and habits of mind” (Bailin et al., 1999, p. 290). They continue by stating that even though some educators continue to see content and the critical thinking process as distinct entities, in reality one must have a thorough knowledge of important concepts within a discipline to engage in deep critical thinking about it. Critical thinking always occurs amid the context of pre-existing knowledge, experiences and values.

Every discipline has at its core a set of standard processes by which theories and ideas are tested, criticized and revised. A critical thinker must have a deep understanding and command of these standards and how they apply to good thinking and inquiry (Bailin et al., 1999). Critical thinking involves many specific strategies which can be applied according to the query at hand. Bailin (1999) incorporates various theorists’ recommendations including: to re-examine both positive and negative outcomes of all possible alternatives; re-confirm before considering something a fact; and divide difficult problems into more manageable parts. He adds that critical thinking does not come automatically to those possessing these intellectual resources. One must also have specific inquiring attitudes and mental habits which make him/her open-minded with a deep respect for reasoning and firm evidence, as well as respect for other's viewpoints in discussion (Bailin et al., 1999).

Robert Ennis continues his work in the field and as stated earlier, promotes the conception of critical thinking as a discrete set of skills, learned independently yet readily transferred between disciplines. He argues that these skills are subject neutral and principles of logic are universally applicable; however, he also concedes that in order to participate in critical reasoning one must first attain a minimal level of competency in a given discipline (Ennis, 2002; Mason, 2007). This widens the debate somewhat with John McPeck who denies that critical thinking can be taught outside the context of a specific discipline, rather it is an essential component of thinking within a given arena (Mason, 2007).

Discipline Specific Critical Thinking

The general critical thinking movement was strengthened by the *Goals 2000: Educate America Act* passed by Congress in the late 1980's, which listed critical thinking as a specific educational outcome (P. A. Facione et al., 1995). This was followed by a nationwide trend among colleges and universities as critical thinking became increasingly marked as a desirable result of undergraduate education. In addition, accreditation standards for health professions educational programs also began incorporating critical thinking as a required learning outcome (German, 2008; JRCERT, 2008).

In radiologic technology, the conversation began in earnest in the mid 1990's when the *American Healthcare Radiology Administrators* (AHRA) queried radiology executives and found that not only did the majority agree that the need for graduates with critical thinking skills was increasing, most survey participants also indicated that students were not being adequately prepared to demonstrate critical thinking on the job (Bugg, 1997; Stadt & Ruhland, 1995). These findings contributed to important revisions in the *JRCERT Standards for an Accredited Educational Program in Radiologic Technology*, which specifically identified competence in critical thinking and problem solving skills as necessary programmatic outcomes. The inclusion of critical thinking as a goal of radiologic technology education has remained constant since this time and has evolved to be more clearly described with each new version of the *Standards*.

The newest revision, which is still in draft form and subject to approval, includes critical thinking in *Standard 3.2* which states in part that; "The program should identify methods used to foster professional values, instill life-long learning, and promote student development of competencies in critical thinking and problem-solving skills." It clarifies this statement by iterating, "these qualities are necessary for students/graduates to practice competently, make good decisions, assess situations, provide appropriate patient care, and keep abreast of current advancements within the profession" (JRCERT, 2008, p. 29). The goal for educators needs to be to develop professionals possessing effective critical thinking skills along with the strong disposition to use these skills. Without these traits, clinicians tend to fall into complacency, fail to adequately analyze patient situations, and blindly perform procedures according to published protocols without reflecting on the potential consequences of suboptimal care (N. C. Facione & Facione, 2008).

Health Professions Education

Competent clinical reasoning and reflective problem solving through critical thinking are ethical imperatives for health care providers at all levels, because human lives are endangered any time poor decisions are made during the course of medical diagnosis and treatment (N. C. Facione & Facione, 2008). In 1999, medical errors accounted for 98,000 patient deaths each year and over a million injuries as well as an estimate that currently 30 – 40 % of all dollars spent on healthcare in the United States are attributed to waste due to inappropriate care and miscommunication (Fero et al., 2009). How many of these errors could be prevented by carefully thinking through complex problems before acting? In reality, all healthcare providers, regardless of specific profession must possess and apply competent clinical reasoning and judgment in the course of caring for patients. In response to this issue, assessing competence in clinical reasoning and problem solving has become standard practice in the workplace as well as a required educational goal for medical and health science programs (N. C. Facione & Facione, 2008).

Turner (2005) analyzes the transition in defining the terminology for critical thinking over the past three decades and states that the current definition used in nursing is well established although there remains a propensity toward using alternative terminology which often causes confusion. Because clinical problem solving, reasoning and decision making are all skills that rely heavily on the cognitive processes inherent in critical thinking, many health professions educators view the terms synonymously (N. C. Facione & Facione, 2008; O'Connor, 2006; Turner, 2005). There are subtle differences however. Jackson, et al., (2006) describe the relationship as follows; "critical thinking is the constant overarching component, the method by which we employ clinical reasoning leading to sound clinical judgments" (p. 14), making critical thinking the central component for development of expert clinical practice. Clinical judgment is defined as making a choice between alternative actions when there may not be a clear direction. Described as "thinking-in-action", the student is open to reassessing and changing actions as the situation warrants (Di Vito-Thomas, 2000). In other words, clinical judgment is the discipline-specific approach to critical thinking (Jackson, Ignavaticius, & Case, 2006).

Although this interchangeable use of terminology seems to be a widespread phenomenon, other scholars including Simpson & Courtney (2002) are careful to differentiate these constructs, defining them specifically while maintaining that each uses critical thinking as a vital component. In fact it may be more appropriate to separate these concepts from critical thinking for the purpose of developing teaching strategies and assessment measures. Intuition and knowledge gained through professional experience enable appropriate clinical reasoning which in turn enhances the ability to make decisions based on clinical evidence, related to a specific patient situation (Banning, 2006). Clinical reasoning and sound judgment then each depend on the development of the cognitive processes used in critical thinking (Di Vito-Thomas, 2000). Appropriate application of critical thinking skills as well as a strong disposition toward their use directly impacts the quality of clinical judgments made. Di Vito-Thomas (2000) describes critical thinking behaviors evident in clinical judgment and citing Bandman & Bandman (1995) identifies types of reasoning involved in critical thinking including deductive, inductive, informal and practical.

Health Professions Practice

The literature describing critical thinking in nursing generally concludes that critical thinking includes the cognitive processes used in decision making and problem solving. Operationalized then; critical thinking in nursing is the synthesis of related evidence and facts, identification of patterns, the formulating of options and possible actions and predicting outcomes during the process of caring for a patient (Di Vito-Thomas, 2000).

In medical practice, external protocols are often developed to guide decisions and actions during routine situations. Even the most complex clinical problems, when encountered regularly, become routine. However, reflective thinking must also always be applied to these protocols to assure they remain appropriate. An important consideration is that the process of clinical reasoning changes as one progresses from novice to expert in a given discipline. With increased experience, the novice gradually becomes an expert and external protocols are enhanced by a series of mental scripts, in which the practitioner recognizes a specific pattern and resolves the problem without conscious reflection (Benner, Tanner, & Chesla, 1996; N. C. Facione & Facione, 2008). Herein lays the danger. One cannot assume flawless reasoning to be the result of expertise. According to Benner et al. (1996), the novice may be prone to errors resulting from inexperience in knowledge application, while the expert is more prone to making errors due to inattention to differences in clinical scenarios. Educators must be vigilant in teaching critical thinking skills and cognitive habits so that students will develop the disposition toward conscious reflection during clinical decision making which must continue as they enter professional practice.

With the exception of three empirical studies, which will be discussed in later sections, critical thinking literature in radiologic sciences is limited in scope. These include mostly recommendations of teaching strategies which are thought to influence the development of critical thinking; or discussion of the importance of matching educational preparation with discreet skills needed in the workplace (Aaron & Haynes, 2005citing Akroyd & Wold, 1996; Dowd, 1991). There is widespread agreement that the ability to engage in appropriate clinical reasoning and sound decision making is a vital skill for all successful radiographers. This ability in turn relies on well-developed critical thinking skills (Adler & Carlton, 2007; Bugg, 1997; Dowd, 1991; Durand, 1999; Martino & Odle, 2006).

Recent and ongoing advancements in imaging technology have led to the rapid development of increasingly complex imaging equipment and procedures. Coupled with these changes in the general healthcare landscape are patients who present increasingly unique challenges due to chronic illness and obesity. A radiography curriculum has traditionally been subject to continual updates to include technological advances in addition to covering many foundational content areas so that students develop a broad base of knowledge (Martino & Odle, 2006). Educators are constrained from possibly covering all applicable content and must therefore promote the development of critical thinking with life-long learning habits in order to give students the tools needed to continue to develop professionally (Bugg, 1997; Dowd, 1991).

Building on the mastery of the necessary knowledge base students must also be able to think deeply, to analyze each situation, synthesize and make application of their knowledge. Educators, challenged with teaching this vast quantity of factual information and its application would be far more effective by promoting critical thinking; leading to students prepared to enter the profession knowing "how to learn" and how to develop the disposition to continue the learning process across their careers (Kowalczyk & Leggett, 2005).

Critical Thinking Defined

The broad definition of critical thinking determined by consensus among interdisciplinary experts is reported in the APA Delphi Report (P. A. Facione, 1990) as: "the process of purposeful, self-regulatory judgment. This process gives reasoned consideration to evidence, contexts, conceptualizations, methods and criteria." This relates to clinical judgment as "critical thinking is the process we use to make a judgment about what to believe and what to do about the symptoms our patient is presenting for diagnosis and treatment" (N. C. Facione & Facione, 2008, p. 2). The cognitive skills identified by this group of experts include: interpretation, analysis, evaluation, inference, explanation and self-regulation. Also identified are the affective traits associated with the dispositions to think critically including the tendency to be inquisitive, open-minded, systematic, analytic, truth-seeking, and self-confident and mature (Banning, 2006; P. A. Facione, 1990; Simpson & Courtney, 2002; Walker, 2005).

Another important consideration is that critical thinking is a process, a mental orientation which includes these affective and cognitive aspects; and is not simply a method to be mastered (Simpson & Courtney, 2002). Critical thinking is only practiced by those with a positive disposition toward it (P. A. Facione et al., 2000; Walker, 2005) therefore it is necessary to purposively teach students both the skills and dispositions related to critical thinking. A disposition toward critical thinking has been defined as "the consistent, internal motivation to solve problems and make decisions" (Walker, 2005, p. 42). In order for students to consistently engage in critical thinking, they must develop these dispositions in addition to the cognitive abilities required (Walker, 2005). Instructors need to be aware of these characteristics, recognize their absence, and be quick to encourage their development during clinical learning (Walker, 2005).

In her dissertation research study, Gordon (1995) demonstrates that nursing educators have a somewhat broader perspective of critical thinking as compared to critical thinking experts from general academic disciplines. She posits that all practice related disciplines likely share this different perspective, which includes research, decision making, problem solving and planning as integral components of critical thinking (Gordon, 1995). Still, consensus for a workable definition for critical thinking has been difficult to attain. Feslar-Birch (2005) describes the on-going progress made since 1912 in deriving a functional definition specific to nursing and attributes much of this progress to another Delphi study conducted within nursing in 2000 which found that it is generally agreed that critical thinking in nursing involves the following cognitive skills: analyzing, application of standards, discriminating, seeking pertinent information, logical reasoning, predicting outcomes and transforming knowledge. In addition, certain dispositions are also identified such as: "confidence, contextual perspective, creativity, flexibility, inquisitiveness, intellectual integrity, open-mindedness, perseverance and reflection" (Scheffer & Rubenfeld, 2000, p. 352). Clarification of the problem at hand and identification of the appropriate solution to address it can only occur through a process of assimilation of knowledge and consideration of applicable data and evidence. This requires application of critical thinking; when nurses thoroughly investigate and reflect upon observations of clinical problems, making sound clinical judgments (Alfaro-LeFevre, 1999; O'Connor, 2006). They use theoretical and factual knowledge and apply critical thinking abilities to procedural and interpersonal aspects of practice in order to implement creative, unique solutions to unpredictable patient situations (Simpson & Courtney, 2002).

In radiography, "what is the consensus definition of critical thinking?" is a question that has not yet been asked. Definitions from the literature are cited and applied without much forethought as to whether they are appropriate to the field. One textbook for entry-level radiographers includes a definition for critical thinking as "creative action based on professional knowledge and experience involving sound judgment applied with high ethical standards and integrity" (Adler & Carlton, 2007, p 41). Another prominent author uses the definition, "an approach to inquiry where both students and faculty examine clinical and professional issues and search for more effective answers" (Dowd, 1991, p. 374). Herrmann and Arnold (Adler & Carlton, 2007; Durand, 1999) combine critical thinking with problem solving and describe it as a process with a series of steps to be followed. These include: 1) identify and/or clarify the problem; 2) objectively examine all aspects of the problem; 3) consider and develop all viable solutions; and 4) select the solution with the best outcome for the patient.

These definitions do nothing to provide a consistent foundation upon which to build the construct within radiologic science and therefore add little to the effort to develop appropriate teaching strategies and assessments. Fortunately, there seems to be a renewed interest and new research is slowly emerging. Most recently Castle (2009) reports results from an empirical study which utilizes a derivative of the widely accepted definition based on Facione's 1990 Delphi study which states that critical thinking is the level of cognitive ability in which "a student is able to interpret, analyze, evaluate, explain and infer concepts and ideas" (p.70).

Academic preparation and critical thinking

Originally, education in medicine and the allied health professions was based on the apprenticeship model, but this has been gradually replaced by academic models consisting of increasing didactic course work complemented by clinical experiences. Research supports this change with studies from multiple allied health professions showing a positive correlation in higher levels of academic preparation, and the inclusion of liberal arts curriculum to increased levels of critical thinking demonstrated (Leaver & Norris, 1999; Rane-Szostak & Robertson, 1996).

Within healthcare, in general, there is a corresponding increase in emphasis on professionals possessing independent decision making and critical thinking skills. Critical thinking and reflective thinking are vital components for the development of life-long learning which is in turn vital for professional growth and development (Banning, 2006).

Many allied health professions have undergone transformation in response to the shifting healthcare landscape. This transformation is needed as professions begin to mature. As a field undergoes changes and clinical practice increases in complexity, an inherent change in educational programs is necessary (Turner, 2005). The entry-level curriculum and academic requirements must change to keep pace. Students must master higher order thinking skills in order to engage in on-going evaluation and application of new knowledge throughout their careers. Students cannot learn to interpret, analyze, infer, explain, evaluate and self-regulate by merely memorizing profuse quantities of discipline specific knowledge. Rather educators must provide a learning environment which establishes active participation as the norm in which students learn these new skills (Turner, 2005). "Stressing education vs. training is thought to produce a graduate with developed powers of judgment, critical thinking and decision making"; certainly one who is better equipped to meet the challenges of a rapidly changing profession (Leaver & Norris, 1999, p. 14). Banning (2006) reports that critical thinking develops through education and while some studies point to a positive correlation between advanced degrees and critical thinking, others link critical thinking to professional experience. Regardless, critical thinking may indeed be more closely related to academic success rather than clinical experience (Stone et al., 2001) and is certainly linked to other professional characteristics such as independent and life-long learning (Marshall, 2008). This debate has led researchers to question just what kinds of changes in critical thinking ability and disposition should be expected with increased academic requirements. Unfortunately while it seems intuitively true that increasing academic preparation should result in better application of critical thinking abilities, empirical studies yield mixed findings.

In the UK, Masters level nursing programs have been developed stressing the importance of critical thinking skills for higher professional practice levels. Studies of these programs however, fail to differentiate between academic level and critical thinking skills developed (Banning, 2006). Another study conducted in the UK cites evidence collected which finds that specific strategies implemented in a postgraduate MRI program are indeed successful in fostering independent learners who develop skills in reflective research, writing and problem solving (Marshall, 2008).

One of the few empirical studies performed to identify differences in critical thinking ability among radiologic sciences students at various academic levels utilizes the *Watson-Glaser Critical Thinking Appraisal* (WGCTA) as a standardized measure. This study reveals a significant difference in critical thinking ability of students enrolled in baccalaureate degree, associate degree and certificate level programs. Students in the BS programs score significantly higher than the other two and those in the certificate level programs score significantly higher than those in AS degree programs (Stadt & Ruhland, 1995). A similar study of Korean nursing students in AS, BS and AS to BSN programs demonstrates a positive correlation between program academic level and critical thinking skills and dispositions evident. Although the mean test scores of all groups falls below the established mean, this study does show that students in BS programs score higher than those in AS programs (Shin et al., 2006).

In exploring the differences in critical thinking among nurses with varying levels of clinical experience and different academic preparations, Fero et al. (2009), identify significant differences between the development of critical thinking over time among graduates of diploma, AS and BS educational programs. Considering experience along with academic preparation, Fero et al. find that those prepared at the BS level demonstrate higher levels of ability after gaining experience as compared to those prepared through diploma programs. These results are inconsistent however with other studies which find no difference between academic levels after ten years of experience gained (Fero et al., 2009).

Aaron and Haynes (2005) conducted a study to determine whether students' critical thinking abilities improve over the course of a two year radiography curriculum. In this study the *California Critical Thinking Skills Test* (CCTST) was administered twice to three cohorts of students in a baccalaureate radiologic sciences program. The test was given at the beginning and end of the program to document developmental gains in critical thinking across the course of the curriculum. Changes in critical thinking among two of the groups are not statistically significant and while changes in the third group are significant, the effect size is small indicating that this change is not likely to indicate a high degree of practical significance (Aaron & Haynes, 2005).

In several other studies, the critical thinking scores of undergraduate nursing students either remain unchanged or demonstrate only small improvements over the two-year educational program supposedly designed specifically to enhance critical thinking (Banning, 2006). The results of these studies raise more questions than they answer. Are the commercially produced critical thinking assessments even valid for standardized testing of critical thinking within health professions? If they are, what do the study results mean? Are current teaching strategies really ineffective for developing critical thinking? Or are educators in health professions actually teaching some other skill such as clinical reasoning or problem solving rather than critical thinking? Is it possible that the difficulty in assessing the construct is that critical thinking as it is currently defined is inappropriately applied to health professions practice?

Teaching Strategies

The healthcare environment of today is vastly different than it was even 15 years ago. Governmental regulations and reduced reimbursement for services by Medicare and insurance companies have led to a transition from in-patient procedures to the utilization of out-patient facilities and services for all but the most serious patient conditions (Bastable, 2003). At the same time, medical knowledge and technological advancements have increased exponentially, changing the face of diagnostic imaging forever. Effective use of clinical education has become even more essential. As the sheer volume and complexity of diagnostic imaging procedures and equipment increases, this requires students to spend a significant amount of time within an imaging department, performing procedures on live patients in order to develop the level of competency expected of new graduates. Unfortunately, at the same time, there are fewer opportunities for students to practice on patients, either because the patient is more critically ill than the student has the knowledge to work with, or the routine procedure which would normally be ordered has been replaced by an advanced modality such as Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) procedure. Because much of the trait we call clinical competency is actually related to sound clinical decision making, we must also carefully cultivate the cognitive and affective components of critical thinking within our students. Psychomotor skills will develop over time and can be practiced on mannequins and standardized patients, but other strategies must be implemented in addition to these to assure our graduates know how to learn and think deeply.

Professional education/practice can be categorized according to two schools of thought. The technical-rationalist approach, based on behavioralism, is the traditional and most common form of education within the health sciences and is often described as the "see one, do one, teach one" method (Banning, 2008). This approach emphasizes competency based skills in technical problem solving by applying scientific knowledge and is based on the apprenticeship model. However, this paradigm hinders progress toward bridging the gap between theoretical knowledge and practice. (Baird, 1996). Because clinical contact hours have been reduced, programs must strive to develop a set of pre-clinical skills which can be practiced and mastered in a class/lab setting prior to clinical application. This serves to increase confidence to perform procedures on real patients. Professional artistry, on the other hand, explores the whole decision making process and is based on clinical judgment, intuition and values; this is a much more complex process (Hall & Davis, 1999).

The prevailing paradigm in education is shifting from a focus on curricular content to that of learning outcomes and must be accompanied by a heightened awareness of the need to teach students to think; to be active learners rather than passive recipients of knowledge (Rane-Szostak & Robertson, 1996). The goal of educators must be to teach students how to reason effectively, analyzing and evaluating new situations and engaging in life-long learning (Dowd, 1991). Since active learning promotes high-order thinking, it is better to change teaching strategies as opposed to endlessly updating curricular content and continuing to rely on traditional teaching methods (Bugg, 1997).

The traditional lecture has long been the default method for teaching students, even in the face of clear evidence showing it is ineffective for long-term retention of factual information and discourages critical thinking and problem solving (Banning, 2008; Cross, 1997). Lectures perpetuate the culture wherein students are passive recipients of knowledge and the teacher is solely responsible for learning (Banning, 2008; Cross, 1997). There are multiple teaching strategies which are effective in developing critical thinking and while they differ greatly in how they are implemented and the steps they incorporate, the most significant commonality is that they all involve active engagement and interaction of the students with the content, the faculty and one another (Banning, 2008; Cross, 1997). These constructivist pedagogies redefine the role of the teacher to that of facilitator of learning (Banning, 2008).

To effectively teach critical thinking, explicit effort must be directed toward developing a curriculum that specifically and systematically focuses on these skills. Marshall (2008) supports the shift away from formal lectures and classroom activities as the primary teaching strategy toward clinically based activities incorporating critical reflection and procedural adaptations as an effective method for developing independent critical thinking. By making students accountable for their own learning, instructors facilitate learning through activities and methods which foster critical thinking and learning. Continuing to rely on the lecture to ensure adequate coverage of the material, actually teaches the student that the required reading is not necessary as the instructor always will relay what they need to know. “Learning can only occur if the student is stimulated to think critically” (Jackson et al., 2006, p. 77).

Equipping students with skills needed for logic and critical thinking does not guarantee they will be able to transfer these skills or to apply them within the context of clinical practice. Critical thinking must be taught in a discipline specific manner, closely related and applied to the specific steps involved in clinical reasoning and decision making. Critical thinking in medicine should be correlated to the scientific method and research methodology and is therefore different in character than critical thinking in general, non-discipline specific applications (Jenicek & Hitchcock, 2005). Situations which require critical thinking include those in which difficult decisions must be made based on changes in patient condition which require modification of procedures or treatments, technical problems or equipment malfunctions (Adler & Carlton, 2007).

To provide optimum patient care in radiography, with its rapidly changing technology and multiple advanced modalities requires independent and critical thinkers (Marshall, 2008) in addition to the ability and disposition toward self-directed and life-long learning (Dowd, 1991). This is accomplished by shifting away from teacher centered activities toward student centered activities which place the responsibility for learning on the student (Sim et al., 2003). Educational programs in Australia and the UK are reporting successful development of critical thinking through teaching strategies developed specifically to support critical reflection and analytic thinking skills through student centered activities (Sim et al., 2003).

Classroom applications

The best method for teaching critical thinking remains under debate. Some propose that separate instruction in thinking skills outside the curricular content is more focused and effective for instilling a cognitive foundation, while others argue that because thinking skills developed in this manner are rarely transferrable, students should be taught how to think within the specific context of their chosen field. In fact, both of these methods may be needed to effectively teach critical thinking. Many propose that providing a course in critical thinking to teach basic thinking strategies before beginning the core curriculum, and then emphasizing the application of those strategies throughout the program is more effective together than using either method in isolation (Edwards, 2006; Fesler-Birch, 2005; Greathouse & Dowd, 1996).

Skillful thinking in any area includes the ability to generate ideas using creative thinking, analysis to clarify them and critical thinking to assess the rationality of those ideas (Fasko, 2003). Educators must teach these thinking skills along with decision-making to assess problem solving strategies in order to develop the thinking tools needed to meet the professional challenges of applying knowledge to real-life situations (Fasko, 2003).

Critical thinking cannot be developed through lectures or even isolated clinical experiences. "Critical thinking is a discipline that must be taught and learned as anything else. It cannot be acquired simply by osmosis from more experienced medical elders" (Jenicek & Hitchcock, 2005, p. 172). It must be developed over time through varied learning experiences which stimulate higher-order thinking in both theory and practice (Simpson & Courtney, 2002). The literature reveals many strategies shown to be effective; including Socratic questioning, collaborative learning activities, role-playing, debate, case based and problem based learning, reflective journals, simulations, complex multiple choice questions, concept analysis, portfolios and other experiences that promote higher order thinking (Adler & Carlton, 2007; Fasko, 2003; Fesler-Birch, 2005; Simpson & Courtney, 2002). Discipline specific content should be infused with critical thinking instruction but only after foundational knowledge has been introduced. (Fesler-Birch, 2005).

Opportunities to use these strategies to develop critical thinking skills occur in the classroom, lab and the clinical setting. Cognitive and psychomotor skills can be practiced in the classroom and lab where students are able to develop and test new ideas and experiment to solve problems without the added stress of endangering a patient through making mistakes (Adler & Carlton, 2007). The knowledge and skills developed in the classroom and lab can then be transferred into action during clinical education experiences where they perform procedures and care for actual patients. Critical thinking develops as students face unique patient situations which deviate from routine protocol and require sound decision making based on application of theoretical knowledge (Adler & Carlton, 2007).

Concept maps

Meaningful learning occurs when students make connections between new information and prior knowledge. Students learn new concepts but these must not remain in isolation. Rather these concepts must be linked to other related concepts (Passmore, 1995). Concept mapping involves creating a diagram of interrelated concepts showing relationships and connections. Concept maps are hierarchical, starting with the "whole" or general concept then progressively differentiating the contributing factors or “parts” (Vacek, 2009). A key concept is placed at the top of a page and lines and arrows are drawn to related concepts and so on. This exercise allows students to visualize how concepts are interrelated and to explore those relationships which may not be immediately apparent (Staib, 2003; Zakus et al., 2007). The concept map is evaluated by the instructor to identify misconceptions, incorrect concepts or false connections. This allows for intervention and remediation of misunderstood or invalid conceptual relationships (Passmore, 1995). Empirical research involving radiologic sciences students shows that concept mapping is an effective tool for improving academic performance in specific course contexts (Passmore, 1995).

Problem-Based learning (Case-based and case-studies)

Critical thinking and problem solving are often seen as synonymous and are specifically linked together in radiologic sciences as a single learning outcome (JRCERT, 2008). In fact, problem solving is more narrowly focused than critical thinking and involves logical reasoning and inference. Pure critical thinking on the other hand involves these factors plus the broader scope of justification, understanding the nature of the problem and tolerance for ambiguity (Kamin, O'Sullivan, Younger, & Detering, 2001). Ironically, in the realities of healthcare, problems must be solved and actions decided as to which will provide the best and safest outcome for the patient. Ambiguity may lead to erroneous decisions and endanger patients and is therefore viewed suspiciously by clinicians.

Problem-Based Learning (PBL) is a strategy commonly applied in medical schools to promote critical thinking. This process involves deductive reasoning while attempting to derive clinical inferences from available data, weighing evidence and recognizing assumptions and distinguishing strong from weak arguments. PBL involves the use of faculty in the role of facilitator rather than teacher. They encourage learners to ask questions and research pertinent information, and encourage development of self-regulation and responsibility (Kamin et al., 2001). Creative thinking is a vital component as students make connections between data and sources, form hypotheses and test them, and make revisions as needed.

Clinical decision making should be taught using approaches which encourage the progressive generation and testing of hypotheses during the use of case studies. During these case studies, the instructor can pose questions which guide the student's thinking processes. To stimulate critical thinking, these questions must be higher order questions requiring the student to analyze the situation as well as the relevant theoretical knowledge (O'Connor, 2006).

Problem Based Learning (PBL) and more recently Case-Based Learning (CBL) are approaches that have been shown to be valuable in teaching communication and decision making skills that enhance clinical experiences (Williams, 2005). PBL involves students working together to consider and solve a discreet clinical case problem. This strategy requires students to make connections between existing knowledge and new knowledge acquired in the course of considering the problem. Students must therefore realize what they already know and be able to find new information to fill in the gaps; and as they learn new concepts must also be able to teach their peers for optimal problem solving (Kowalczyk & Leggett, 2005). Students work through realistic patient situations and sometimes virtual patients, interacting with clinical data, to form conclusions regarding diagnoses and treatment options based on their findings. This is a form of experiential learning which is performed outside the clinical environment but has direct correlation to the skills typically obtained there.

Socratic questioning

When students actively participate in learning, they may retain factual knowledge and develop critical thinking skills more effectively. Interactive learning is fundamental to the development of high order cognitive abilities needed for critical thinking. This interaction can be promoted by the appropriate use of questioning during classroom activities as well as during lab or clinical learning (Edwards, 2006; Staib, 2003; Tanenbaum et al., 1997; Wink, 1993). Socratic questioning is a technique specifically designed to stimulate thinking and encourage reasoning skills (Tanenbaum et al., 1997; Wink, 1993). Questioning is also an integral component of other strategies discussed such as PBL/CBL, simulations and clinical reflection. It helps students practice the thinking skills needed during clinical decision making. As students are called upon to recall knowledge and then apply it appropriately through evaluation and analysis, they receive feedback regarding the accuracy of their responses thereby allowing them to see their own strengths and weaknesses, providing motivation to improve (Edwards, 2006; Staib, 2003; Tanenbaum et al., 1997; Wink, 1993).

Whether in a classroom setting or when integrated into individual sessions between student and faculty, questioning serves multiple purposes. Initially, questions serve to assess the student’s mastery of foundational knowledge and are an excellent way to start class discussions. Not only does questioning serve to assess knowledge and comprehension levels, it also focuses students’ attention and keeps them alert during class. It provides opportunities for encoding and rehearsal of new concepts which contributes to feedback enhancing learner motivation (Edwards, 2006; Staib, 2003; Tanenbaum et al., 1997; Wink, 1993). To be effective, questions should lead the students from basic recall of facts through the process of comprehension, application, analysis, synthesis and evaluation. Evaluation questions are the most crucial because they lead the student to ponder the silent questions internally answered by expert practitioners in clinical situations. In doing so, the student develops the ability to identify pertinent data, and cues used toward their conclusion thus becoming aware and reflective of their own thinking processes (Wink, 1993).

Collaborative Learning

Teacher centered strategies must be replaced by those which are student centered in order to build critical thinking and reasoning skills, to increase student creative thinking and cognitive independence and give them a sense of ownership and personal responsibility for their own learning (Kowalczyk & Leggett, 2005). A teaching strategy which overlaps with many of those presented here and is in itself perhaps the most vital link in developing critical thinking is that of collaborative learning. Active engagement with the curricular content, faculty and peers requires a deeper level of thinking. Collaborative learning occurs when students of all levels work together in small groups in order to accomplish a common goal, thus maximizing learning outcomes for all (Hicks, 2007; South-Winter, 2005; Yates, 2006). Group members are motivated through positive peer pressure to help each other master the content so that the group as a whole might be successful. Students learn from each other through informal discussions, developing a shared understanding of the concepts in a non-threatening environment (South-Winter, 2005).

Clinical practice in healthcare requires collaboration of interdisciplinary teams to actively solve problems regarding patient diagnosis and treatment. Radiographers are vital members of these teams and must likewise exhibit excellent communication, collaborative problem solving and critical thinking skills (Hicks, 2007; South-Winter, 2005). Studies support the use of collaborative learning for developing high level cognitive skills such as those used in critical thinking and problem solving in addition to higher overall academic achievement, self directed learning and enhanced professional skills such as communication and teamwork (Hicks, 2007; Kowalczyk & Leggett, 2005).

Research strongly supports the premise that working in a group to reach a common goal produces greater achievement and superior productivity than working alone. Indeed significant improvement in all higher order cognitive skills used for critical thinking is shown in students engaged in collaborative learning activities (Yates, 2006).

Clinical applications

Fasko (2003) argues that while these methods do promote deep understanding and critical thinking skills, it is important for teachers to explicitly prompt students to reflect on their thinking if they are to fully develop skillful thinking and apply it to all areas. “Critical thinking and reflective practice are interactive, intertwined processes that enable the student to build upon knowledge acquired in the classroom through thoughtful consideration of and active involvement in the contextual complexity that is present in the clinical setting” (O'Connor, 2006, p. 176).

Students learn the habits of mind associated with critical thinking over time through guidance and from observing faculty role models as they engage in critical thinking. “If we are to teach health science students how to better approach clinical problems, it is imperative that we train ourselves to be better at hearing the thinking of those we mentor and skilled at helping them to analyze their thinking for its quality” (N. C. Facione & Facione, 2008, p. 280). Clinical practice is vital since it is in making observations and engaging in problem solving during direct patient contact that the student is able to develop the cognitive and affective skills inherent in critical thinking. During clinical experiences learning occurs from success and failure. Educators must take advantage of opportunities provided by both. In reality, instructors often inadvertently teach students to avoid risk and cover up mistakes rather than to learn from their failures. Instead, students should be encouraged to learn from all aspects of clinical experience (Benner et al., 1996).

Critical Reflection

Clinical reasoning, like critical thinking is a cognitive process in which allied health professionals make decisions about the diagnosis and treatment of patient conditions through careful observations and evaluation of pertinent clinical data using both inductive and deductive logic (Banning, 2008). In addition to domain specific knowledge, subcomponents of clinical reasoning include intuition and experience which are thought to be characteristics exhibited only by expert practitioners.

Think-aloud Approach

One effective strategy for teaching reflective practice and thus critical thinking is the encouragement of a think-aloud approach in which the student verbalizes his/her thought processes while thinking about and performing some clinical task (O'Connor, 2006). The think-aloud approach involves students verbalizing their thoughts as they investigate a topic or work through a real or simulated patient care situation; evaluating as they make observations; identifying interrelated happenings; and making connections between theory and practice. This allows them to make decisions about appropriate actions and behaviors. In addition, educators are able to hear and assess the student's thought processes and gain insight into his/her ability to make connections between core concepts and related information, as well as to identify correct or faulty reasoning or errors in fact (Banning, 2008).

Self-Evaluation through Reflective Journaling

To ensure personal and professional growth and intellectual development, students must be able to reflectively report on their experiences. They should be able to discuss and justify their actions and evaluate the consequences to rationalize changing future behaviors in similar situations (Baird, 1996). The process of self-evaluation in which students provide anecdotal records of their progress toward achieving learning objectives and decision making skills is another valuable tool for the development of critical thinking through reflective practice. This allows students to determine their own areas of strength and weakness and motivates them to make progress (O'Connor, 2006). Self-evaluation is really just critical thinking applied to personal performance (Edwards, 2006) and is fundamental to the ability to think critically;

allowing one to move beyond standardized thinking and routine procedures (Zakus et al., 2007). The writing and maintenance of a reflective journal should involve self-critique; what was done well, and what corrections or improvements are needed. The student should keep a record of progress throughout the program, including accounts of unusual or challenging patient situations with outcomes and also reflect on the impact of the event on their professional practice and personal development (Edwards, 2006). More specifically, clinical journals should document objective and subjective observations, discuss alternative actions, explore and critique ideas and actions, and reflectively analyze and evaluate personal experiences (Staib, 2003; Zakus et al., 2007).

Journaling can be an effective tool for encouraging critical reflection on clinical experiences and helps students see beyond the development of technical expertise and textbook theory to the realities of providing optimum patient care. Journals can be used to meet a variety of goals and objectives, but generally should require the students to record their affective responses to clinical experiences. It is helpful to specifically detail what should be included by providing stimulus questions, discussion points or some other consistent format to be followed (O'Connor, 2006). Critical reflection incorporating reflective writing allows students to explore clinical situations by evaluating their actions through the lens of attitudes, beliefs and values. This learning activity has been used effectively to foster critical thinking in many allied health programs (Francis, 2008).

Critical thinking is enhanced when students are taught to engage in “reflection-on-action. This involves retrospective observations about actions taken and consequences experienced.

Learning certainly occurs through this process; however, since this does not allow the student to change the past, reflection–in-action should be the desired goal (Hall & Davis, 1999). Both of these processes are important aspects of "thinking on your feet". This reflection-in-action allows the student to make judgments and change actions as appropriate thus adapting to unique situations to ensure the best patient outcomes possible (Hall & Davis, 1999). Schon (1995) defines this as dynamic thinking which serves to change actions while they occur or "on-the-spot experimentation" (Clouder, 2000).

Clinical debriefing

Debriefing is a method used in many nursing programs in which students meet together at the end of the clinical day to share their experiences and personal responses. They are able to express their doubts and fears arising from difficult clinical situations and begin to see these problems as solvable. These collaborative sessions focus on critical appraisal of personal and peer practices and experiences and allow students to construct new knowledge and problem solving abilities (O'Connor, 2006; Wink, 1995).

Assessment Methods and Tools

In developing or selecting an assessment tool, the first step must be to define the construct to be assessed. Because critical thinking is perceived differently by so many, each program must identify related educational goals and objectives and specifically define what is meant by critical thinking in its own context. Once this definition has been established choosing the appropriate method of assessment is then possible. Ideally, the assessment tool should measure educational gains over a period of time. Critical thinking tests which measure aptitude may have a valid purpose for things such as admissions criteria in order to identify those most likely to be successful in the program. However, since aptitude is considered an unchanging characteristic, this type of test will not provide a reliable measure of whether critical thinking abilities are developing throughout the course of the program (Rane-Szostak & Robertson, 1996). Another consideration is that the assessment must be designed so that by administering it at the beginning and again at the end of the program, changes in critical thinking ability resulting from participating in the program are reliably documented, and differentiated from other factors such as occur through the maturation process (Rane-Szostak & Robertson, 1996).

Critical thinking is a broad based concept with numerous accepted definitions, most of which contain multifarious descriptions which seem to add to the confusion. The complexity of critical thinking makes it difficult to operationalize and therefore difficult to correlate to specific teaching strategies and likewise, difficult although not impossible to measure (Ennis, 1993). Assessing critical thinking at a distinct point in time such as in the case of evaluating student performance during as assigned task is certainly beneficial, and aids in diagnosis and feedback regarding that student's ability. For programmatic assessment however, it is necessary to measure changes in critical thinking ability which occur as a result of teaching and learning across the curriculum.

To demonstrate program effectiveness, assessment of critical thinking should occur before and after completing the curriculum (Aaron & Haynes, 2005). Some sort of pre/post test format would normally be useful here because this design measures changes over time.

Assuming that critical thinking can indeed be learned, it may not necessarily be evident in students at the beginning of a program. Conversely, based on the supposition that critical thinking is discipline specific, then one would expect that pre-test scores would be very low compared to post-test scores, and not really a valid comparison at all. Because of this inherent incongruity, the use of standardized general critical thinking assessments cannot overcome these obstacles and their validity as a measure remains questionable. Like the other health professions, there is no discipline specific test to measure critical thinking in radiologic sciences (Aaron & Haynes, 2005).

Assessment is important as a means to inform educators regarding effectiveness of their efforts in teaching these skills in addition to overall curricular success. A variety of assessments can be used to gain insight into whether changes should be made in the curriculum or teaching strategies (Ennis, 1993). The JRCERT dictates that radiography programs report critical thinking ability as a learning outcome. This requires that programs not only teach these skills but also have valid and reliable assessment measures documented. Even though standards require the assessment of critical thinking as a programmatic outcome, its definition and acceptable methods of assessment are not addressed, leaving individual programs with the responsibility of determining how to teach and assess this ability (Aaron & Haynes, 2005). Of the many teaching methods proposed, little insight has been gained from the few which have been studied empirically; indeed most of the evidence cited is anecdotal in nature as researchers have been unable to demonstrate statistically significant improvements in critical thinking skills or abilities linked to these educational interventions (Staib, 2003).

The development of assessment and measurement tools to evaluate the effectiveness of critical thinking instruction lags behind the integration of specific teaching strategies thought to be effective (Staib, 2003). Commercial tools are available, but none of them have been proven valid or reliable for the purpose at hand (Staib, 2003). Of the numerous standardized tests used in health science educational programs, the most common are the *Watson-Glaser Critical Thinking Appraisal* (WTGCA), the *California Critical Thinking Skills Test* (CCTST) and the *California Critical Thinking Dispositions Inventory* (CCTDI) (Banning, 2006; Staib, 2003). Studies using these general critical thinking tests attempting to demonstrate positive correlation with discipline specific decision-making skills have not been successful. Consequently, while these general critical thinking assessment tools have been shown to have a high degree of validity and reliability for general assessment, they do not seem to adequately measure the content specific skills taught within a health profession's curriculum and therefore are probably not appropriate tools for such purposes (Morrison & Walsh-Free, 2001). Because application of critical thinking is discipline specific and builds upon the factual knowledge gained across a curriculum, the students most likely develop the ability and skills needed for critical thinking as they progress and learn. This premise offers one explanation as to why the development of critical thinking has not been accurately measured between program entry and completion; perhaps it should only be assessed systematically as the student progresses and builds upon his/her knowledge (Morrison & Walsh-Free, 2001).

Commercially produced test instruments can be quite useful as long as the test is matched to the goals and definition established by the program (Rane-Szostak & Robertson, 1996).

Research in nursing reveals that critical thinking may be evaluated differently by a given program based on the accepted definition applied by the faculty (Videbeck, 1997). The same may be true of radiologic sciences. Videbeck (1997) reports the results of a study of BS level nursing programs performed to identify the applied definition as well as evaluation/measures used in reporting critical thinking measures to the nursing accreditation body. She finds that the various definitions provided include both affective and cognitive abilities. Reported assessment tools include standardized critical thinking tests, locally developed tools and course specific objectives such as written assignments, clinical performance objectives and course exams. Some of the locally developed instruments described in this study which may also have broader applications in other health sciences include:

- Clinical judgment tool administered at the end of each clinical course and compared across semesters to measure changes in critical thinking
- Critical thinking appraisal multiple choice test administered at graduation
- Critical thinking survey, self-report tool completed at the beginning and end of the program
- College developed outcomes assessment
- Clinical case studies completed at the beginning and end
- Course specific measures including written exams, clinical performance evaluation and clinical written assignments such as patient care plans, case studies and journals

Rane-Szostak & Robertson (1996) identify several important considerations for choosing an appropriate assessment method. These include ensuring the definition matches the construct being tested by the selected instrument, as well as reliability, validity, and sensitivity of the test scores to the expected outcome.

Performance Assessment

Portfolios and Test Instruments

A common method for measuring critical thinking is the test format. Multiple choice questions are often used, however essay style tests are considered more valid (Aaron & Haynes, 2005). Ennis (1993) outlines five purposes of multiple choice test items including diagnosis, feedback, motivation, impact of teaching and research. The challenge is to ensure that the questions require higher order thinking such as synthesis, analysis and evaluation as opposed to simple knowledge recall. Indeed, multiple choice test items can be highly effective for evaluating knowledge and critical thinking assuming they are properly written, require application of multi-logical thinking, as well as a high level of discriminating judgment to select the best answer and application to clinically oriented situations (Morrison & Walsh-Free, 2001). Properly written multiple choice test items are also an effective learning tool because students are generally highly motivated to learn in order to do well on a test. To benefit from the testing experience, students should be encouraged to analyze their thinking about test items and be able to describe their rationale for choosing or not choosing each response (Morrison & Walsh-Free, 2001).

Standardized tools of general critical thinking abilities and dispositions exist and are widely used in many allied health professions, especially nursing. However, there is much dissatisfaction reported regarding the results of many research studies. Since none of the current tools is specifically designed to correspond to clinical disciplines (Simpson & Courtney, 2002), there remains a tremendous void in this area. Alternative forms of assessment have been suggested and are in use to varying degrees, but with unknown effectiveness. These include concept mapping, portfolios, and analysis of specific writing assignments such as reflective journaling (Simpson & Courtney, 2002). Performance assessment involves evaluating students as they demonstrate clinical problem-solving skills during complex clinical situations. Observations can be made directly or through the use of simulated scenarios either with live actors or computer based cases.

Portfolios are gaining in popularity and have been proposed as an effective strategy to develop critical thinking in students, and may also provide an effective means to demonstrate growth over the course of an educational program. A well-designed portfolio allows the student to think reflectively about multiple areas of learning and performance and select examples of his/her best work to document progress. Thus the process prompts the students to think critically by analyzing how their actions identify both positive and negative outcomes. This in turn provides a valuable source of documentation for programmatic assessment of teaching strategies and learning outcomes (Kudlas, Davison, & Mannelin, 2003).

Castle (2009) presents a method for assessment of six components thought to be key to radiologic science students including the abilities "to interpret, analyze, evaluate, explain and infer concepts and ideas" (p. 70). His discipline specific assessment tool, a *Critical Thinking Skills Scoring Chart*, provides structure for analyzing students' written performance during a series of assigned learning activities spread over the course of a three-year baccalaureate program. This chart was used in a research study which found that some students were able to perform satisfactorily in each dimension identified while others were not; and that some dimensions proved to be more of a challenge than others. The assessments were administered to students at distinct points in time corresponding to their progress in the program and the expectations as to which skills should be evident (Castle, 2009). This study is an important milestone for radiologic sciences because it helps establish the importance of developing a model to be used consistently in order to identify weaknesses in curriculum design, which can then be systematically addressed.

Assessments which are criterion-referenced are most useful for measuring students' understanding, ability to synthesize and apply knowledge and to think critically (Rane-Szostak & Robertson, 1996) because this type of assessment is performance based and developed to demonstrate a certain level of competency or mastery. In contrast, norm-referenced assessments are designed to compare students by ranking them according to ability. This will not guarantee that any have attained a desired level of ability (Rane-Szostak & Robertson, 1996).

Summary

The need for developing critical thinking in radiologic science students is well documented though professional standards and requirements. The professional *Code of Ethics* published by the ARRT addresses expectations that radiographers perform procedures in a manner that ensures optimum quality, patient safety and ethical integrity (Adler & Carlton, 2007). *Professional Practice Standards* are published by the ASRT which further define expectations and responsibilities. Inherent in these are the "elements of appropriate decision making skills associated with problem solving and critical thinking" (Adler & Carlton, 2007, p. 42). In order to effectively teach clinical reasoning, we must teach with a focus on the critical thinking processes used to "interpret, analyze, infer, evaluate and explain what is going on". Educators need to present learning activities which facilitate reflective problem solving and involve self-evaluation of the clinical reasoning process by the student (N. C. Facione & Facione, 2008). Evidence of improved critical thinking is being documented in disciplines which are incorporating appropriate pedagogies such as case-based and problem-based learning, although more empirical research is needed to strengthen the case for relying on these strategies. Continued exploration into how to best assess critical thinking must be a priority among radiologic science educators and professionals in order to establish the foundation for further study of this vital professional skill.

CHAPTER THREE: METHODOLOGY

Chapter three delineates the methodology applied to this study including the research design, selection of participants, and development of the survey instrument. The research questions, hypotheses and data analysis procedures are also presented. This study is both descriptive and exploratory. Data were collected via a previously developed survey instrument (Gordon, 1995), adapted by the researcher and administered using the commercial survey tool, Survey Monkey®. This survey was distributed to all JRCERT accredited radiography programs in the United States. The instrument solicited information regarding the perceived definition of, and the skills associated with critical thinking by the participants; reported teaching strategies and assessment methods; and reported programmatic critical thinking measures. These data were analyzed using both descriptive and inferential statistics to determine how and how well radiologic technology as a profession addresses this vital issue.

Research design

This quantitative study used a cross-sectional survey format in order to collect data from a stratified sample of educational programs in the radiologic sciences. The survey tool was a self-administered questionnaire delivered to the respective programs via email with a link to the survey embedded in the message.

The survey format was chosen in order to expedite data collection across a broad cross-section of the population of radiography programs. According to Shavelson (1996), the benefits of a survey design include the ease of including a large number of participants in the study sample, the efficient use of time and general cost effectiveness. In designing this study, care was taken to avoid common statistical errors. Type I error, referred to as alpha (α) is the probability of rejecting a null hypothesis that is actually true. Type II error or beta (β) is the probability of not rejecting a null hypothesis that is in fact false. Power on the other hand, is defined as the probability of correctly rejecting a false null hypothesis ($1 - \beta$) and should be maximized while minimizing α, or Type I error (Shavelson, 1996).

Population and Participants

According to the JRCERT database (2009), there are 628 accredited radiography programs of various academic levels active in the United States, including 34 baccalaureate degree programs (5.4 %), 390 associate degree programs (62.1 %) and 204 certificate programs (32.5 %). Questionnaires were sent via email with an embedded link to the instrument to the program director of each of these accredited radiologic sciences educational programs. Only program directors were solicited to participate in an effort to control for variability that might result from the broad range of educational backgrounds of program faculty. Many faculty hold BS or AS degrees and are primarily clinicians with varying degrees of educational experience. Knowledge of educational theory may also vary widely. Because JRCERT requires that program directors have attained at least a master's degree, it may be more likely that they would also possess more consistent levels of knowledge on the theoretical basis of critical thinking.

Sample size and characteristics

To minimize the possibility of error and maximize the power of statistical analyses, several scenarios were considered. As a general rule, to reduce sampling error, programs should be selected for participation randomly from the stratified populations using a random numbers generator. To generate results with acceptable power, sufficient sample sizes must be assured. Based on a population size of 628, a desired power of 80 %, confidence level of 95 % and an alpha of 0.05, the appropriate sample size was calculated as 238. Assuming a 50 % response rate, 476 programs should be solicited for participation. Furthermore, considering that programs were identified based on stratification by terminal degree awarded, applying similar percentages to this sample showed the need to solicit of 24 BS degree programs, 395 AS degree programs and 157 certificate programs. On the other hand, considering that data analyses were also to be conducted on each subgroup in addition to the comparisons to the total population, power should also be assured for each stratum. Recalculation of the sample sizes needed to obtain a confidence level of 95% with an alpha of 0.05 for each subgroup showed that for 80 % power to be obtained, 31 BS degree programs, 194 AS degree programs and 136 certificate programs would need to participate. Again, accounting for a 50% response rate, all programs at each level actually needed to be solicited to assure optimum statistical power across each stratum; since the calculations showed that the number of needed solicitations was equal to/or greater than the total population for each. For comparison, see Table 1.

Table 1: Calculated sample sizes needed for 80 % statistical power

Academic level	Population total	# of solicitants considering total population power	# of participants needed considering power of each strata	(Adjusted for response rate)
BS	34 (5.4 %)	24 (5 %)	31	(62)
AS	390 (62.1 %)	295 (62 %)	194	(388)
Certificate	204 (32.5 %)	157 (33 %)	133	(266)
Total	628	476	358	(716)

(Custom Insight, 2009)

Considering these factors, and striving for valid results, it was decided to use a census population for each of the strata. While this was no longer considered a random sample, the results were still stratified for analyses and reporting. Because of the unusually small size of the BS degree population, additional efforts were incorporated to ensure the highest possible response rate. These are discussed in the procedures section of this chapter.

Questionnaire Development and Revision

A questionnaire was developed in two stages by the researcher by adapting a similar survey used in prior research of nursing perspectives of critical thinking as compared to expert consensus (Gordon, 1995). Stage one involved adaptations of the original survey developed by Gordon (1995). This revised tool was used in a pilot test to further refine and clarify items. Specific feedback was incorporated and further refinements made. These refinements resulted in the final survey tool and are described as stage two. The survey instrument developed in stage one and used in the pilot test is included as appendix B and the resulting instrument developed in stage two is included as appendix D.

Initial revisions for stage one were made according to *Dillman's Tailored Design Method* for effective formatting and methods of conducting internet surveys (Dillman, 2000). Permission was granted by the author of the original survey to use any portion of the instrument intact or to revise it as needed. See Appendix A for permission letter. The seven research questions were addressed through analyses of responses to the questions modeled after Gordon's study which effectively identified the commonalities and differences between the critical thinking definitions and perceptions of nurse educators compared to those of recognized critical thinking experts (Gordon, 1995). The revised survey then, asked comparable questions to establish a relationship between critical thinking definitions and perceptions of radiography educators, and used those of nurse educators as a foundation since the professions are similar in practice and educational curricula.

Stage One – Initial Questionnaire Development

Research questions one, two and three were descriptive and were addressed with items in questionnaire parts one through four which queried participants regarding actual practices, strategies and assessment methods used within each program, as well as perceptions of the skills, abilities and dispositions involved in critical thinking. Research questions four through seven analyzed differences in these perceptions identified based on demographic characteristics collected in part five of the questionnaire.

Appendix C contains tables identifying the rationale provided by Gordon for inclusion of the items found in each of the following sections of the survey instrument.

Part one of the questionnaire contained items which pertain to the respondent's perception of what critical thinking looks like in the radiologic sciences. A five point Likert scale was applied to 18 statements regarding the definition applied to critical thinking and statements assessing the perceived effectiveness of current efforts. Questions included: Are problem solving and/or clinical judgment the same as critical thinking? Is a standard definition of critical thinking within radiologic science needed? Is critical thinking in radiography conceptually different than critical thinking in other allied health professions? Additional items asked how critical thinking is incorporated into the curriculum (via a formal, separate course, integrated within limited courses, integrated within clinical courses only, etc). What teaching methods does your program use to promote critical thinking (CBL/PBL; reflective journaling, collaborative learning, Socratic questioning, etc.)? How do you rate your programs success at developing critical thinking? And, if critical thinking is reported as a programmatic outcome to JRCERT, what measures are used in this report?

Part two provided a list of general critical thinking concepts and asked the participant to indicate whether the concept is synonymous with critical thinking, only partially involving critical thinking, or completely distinct from critical thinking. The items in the list were originally compiled by Gordon (1995) based on Facione's Delphi study (1990), higher order thinking skills and concepts from the nursing process (Gordon, 1995).

Part three contained a list of characteristics or dispositions of the critical thinker. These items were also taken from the Facione Delphi report (1990) and distracters added based on the characteristics of a professional, the nursing process and clinical judgment (Gordon, 1995).

Part four provided a list of skills and abilities related to the accepted critical thinking categories of: interpretation, analysis, evaluation, inference, explanation and self-regulation (P. A. Facione, 1990; Gordon, 1995). Also included in this list were skills considered in clinical reasoning, the nursing process, intuition, creativity and ethical decision making (Gordon, 1995). See appendix B to view a copy of the survey instrument used for the pilot study and appendix C to view tables identifying the rationale for item inclusion.

Part five of the questionnaire contained questions about basic program demographics for identification purposes and included terminal degree awarded and program size as measured by the number of first year students enrolled annually. Other items to be used to gain a broader perspective during data analyses included academic and professional credentials and number of years teaching experience of the individual completing the tool; and an indication of how the respondent developed his or her personal perception of critical thinking.

To maintain the ability to subsequently consider the findings of Gordon's study (1995) as a foundation upon which to build an understanding of critical thinking within radiologic sciences, Gordon's survey questions were closely followed including her items related to the identification of critical thinking skills and abilities, clinical reasoning skills, intuition, creativity, ethical decision making, and critical thinking dispositions (Gordon, 1995).

Pilot Study

Prior to starting the formal research study and after receiving separate IRB approval, a pilot study of the stage one survey instrument was conducted. A total of 29 questionnaires were sent out for this purpose. The pilot study was performed to provide the researcher with feedback regarding the appropriateness and clarity of the questionnaire items and responses and to identify problematic items. A convenience sample was used for this purpose.

One portion of the sample included a small group of radiologic sciences educators from the researcher's institution and three other programs located in the same geographical region. These programs were selected because the researcher is known by the educators at these institutions thus increasing the probability of participation and rapid completion of the survey. Also considered was the fact that inclusion of these specific institutions provided input from each of the classifications of academic levels (AS, BS and Certificate) to be assessed in the subsequent research study. Informal contact was made by email to establish a willingness and ability to participate in the pilot study.

The second portion of the sample was also a convenience sample made up of colleagues from other health professions programs at the researcher's institution. The rationale for inclusion of these participants included the assumption that these other allied health professions were similar in their clinical thinking processes and these educator's likely had a broad based understanding of critical thinking within their own professions which provided valuable insight into the appropriateness of the survey instrument. In addition, the sample included two critical thinking experts outside the researcher's institution identified through informal discussions with colleagues.

The pilot questionnaire was formatted and designed using Survey Monkey®. A formal request for participation in the pilot study was emailed to each identified individual. The request included a description of the purpose of the pilot study, a specific request for feedback on item clarity and appropriateness, and a request for an optional follow-up phone interview by the researcher. Respondents were informed that consent was implied by clicking on the link opening the survey.

Following the initial request for participation, the researcher received 16 responses with seven individuals affirming that they were interested in a follow-up interview to discuss the questions and format. After ten days, a reminder email was sent to those who had not yet responded. This resulted in nine more responses received. The pilot study resulted in a total response rate of 86 %. Participants represented all of the health professions solicited. See table 2 for a summary of solicitations vs. participants.

Table 2: Summary of participants in pilot test of survey

Profession	**Solicited**	**Participating**
Radiologic Science	12	11
Physical Therapy	6	5
Athletic Training	2	2
Cardiopulmonary sciences	2	1
Nursing	4	4
Communication Disorders	1	1
Miscellaneous	2	1
Total	29	25

Stage Two – Tool Refinement

Results of the phone interviews and other feedback received were analyzed and incorporated in questionnaire revisions as indicated. The original questionnaire was designed to build on Gordon's findings which compared the definition of critical thinking according to Facione's Delphi study to the perspective of nurse educators. It included multiple sections with numerous items related to: *critical thinking Skills and Abilities; Characteristics of Critical Thinkers; Related Concepts; General critical thinking Concepts; and Respondent Demographics*. The pilot test of this tool revealed that there were several problems which needed to be addressed. The sheer length of the tool in addition to the long lists of sometimes redundant items made the questionnaire tedious and confusing to complete. Many of the items were difficult to answer due to lack of clarity or differing perspectives.

Part one of the *Stage One* instrument was revised to ease completion and provide clarity. The items were separated into two main components, relabeled Parts A and B. Part A, *Critical Thinking in Radiologic Sciences*, maintained the original list of 18 items from Gordon's structure identifying general critical thinking concepts as related to radiologic sciences to be rated using a five point Likert scale. This was followed by items to identify how programs structure their critical thinking instruction; whether in specific critical thinking courses or integrated across the curriculum. Part B, *Teaching Strategies,* deviated from Gordon's instrument which sought to identify teaching strategies used to promote critical thinking. This was divided into two components.

The first part of asked the respondent to indicate whether specific teaching methods and learning objectives listed were considered effective to promote critical thinking. Subsequently, the second part followed with the same list and asked to what extent each of the strategies was currently in use by the respondent's program. Part C, *Assessment Measures*, used a similar format by listing potential assessment measures and first queried whether the respondent agreed or disagreed that each is an appropriate means of assessment for critical thinking. This was followed by the same list with instructions to select any items which are currently used to report to the JRCERT as programmatic outcome measures.

Parts two, three and four of the original survey sought to identify the perceived definition of critical thinking by nurse educators using separate lists of *critical thinking Skills and Abilities*, *Characteristics of Critical Thinking* and *General critical thinking Concepts*. Many of these items were unclear and somewhat redundant. These were simplified and compiled into Part D of the revised instrument. Core statements were taken from Facione's Delphi study which identified skills and abilities as well as dispositions needed for critical thinking. Distracters were added based on skills identified by Facione as distinctly different than critical thinking and other characteristics taken from Gordon's research regarding clinical reasoning, clinical judgment, the nursing process, and higher order thinking skills. Table 3 is included to identify the source of each item included.

Part E, *Program and Faculty Demographics*, remained relatively unchanged from the original instrument and served to identify academic level, institution type, program size, and faculty characteristics such as academic preparation, years' experience and how the respondent developed his/her perception of critical thinking. The order of the items in the demographic section was based on a coherent flow of information, while the other sections were randomly ordered to avoid response set bias.

Table 3: Critical thinking attributes; Rationale for item inclusion

Facione's Delphi Study	Clinical judgment/ reasoning	Nursing process	Higher order thinking	Non-critical thinking attributes (Facione)
Problem solving	Recognizing cues	Implementing a plan	Deductive reasoning	Empathizing
Adapting protocols based on analysis of a situation	Reasons to make decisions, diagnose problems, project outcomes	Reasoning intuitively	Judging evidence to be more or less important	Sensing (seeing, touching, hearing)
Judging the credibility of a source	Has growing sense of responsibility for patient outcomes	Using clinical judgment	Applying reflective skepticism	Conducting research in a discipline
Interpreting data on a table or graph	Exploring ethical issues impacting a decision		Using higher cognitive thinking	Interrogating, cross-examining
Defending an opinion			Inductive reasoning	Motivating others
			Following protocols	Managing others
			Exercising reflective reasoning	Reading
			Performing routine procedures	Communicating verbally
			Thinking creatively	Speaking or writing
			Thinking about thinking	Planning

Validity and Reliability

The piloted survey instrument was a modified version of a questionnaire used in a prior research study comparing the perception of critical thinking by nurse educators to the expert consensus determined by Facione in 1990 (Gordon, 1995). Gordon developed the original questionnaire and tested its construct and content validity using input by critical thinking experts within the nursing profession and the result of the APA Delphi study using a panel of general critical thinking experts. Gordon (1995) assessed reliability of the original instrument using a test/retest method which revealed a correlation coefficient of 0.96, a correlation of 0.75 for the characteristics section, 0.76 for the skills section and 0.45 for the concepts section. Additional reliability testing was not conducted on the pilot version of the questionnaire.

The instrument was enhanced to include statements specific to radiologic sciences and through modifications made according to feedback received during the pilot study. Content and construct validity were again ensured by critique of the questionnaire by a critical thinking expert within radiologic sciences who was concurrently involved in research on critical thinking in radiologic sciences and by other allied health educators experienced in teaching and assessing critical thinking in their respective professions.

Materials

No special materials were used to perform this research study. The survey instrument and all communications were delivered electronically via email. The email addresses of the participants were obtained through the JRCERT database which is publically accessible. Data was collected through the Survey Monkey® website and the researcher analyzed the results in aggregate form only, maintaining the anonymity of the study participants.

Procedures

The researcher sought approval from the UCF Institutional Review Board (IRB) prior to beginning both the pilot test and the formal research study. A waiver of documentation of consent was requested as opening and completing the survey was interpreted as consent to participate. Notification was received from the IRB indicating that the pilot study was exempt from oversight as its design was not classified as human subjects research as defined by the IRB. Subsequently, the IRB also ruled that the formal research study was exempt from regulation. Both notices are included in appendix F.

External validity, which assures generalizability of results (Shavelson, 1996), was addressed by including all programs from each of the academic levels represented. Due to the small population sizes of BS and certificate level programs, a census of each of these populations were invited to participate (see Table 1). All of the AS degree programs were also solicited because the calculated required sample was almost the entire population.

The questionnaire was administered via e-mail according to *Dillman's Tailored Design Method* (2000) for internet surveys. Copies of all survey correspondence are included in appendix E. An initial pre-notice email was sent on April 2, 2010 introducing the researcher, describing the purpose of the study and requesting participation. Sixteen participants were blocked because each had previously opted out of receiving any type of solicitation from Survey Monkey®. An additional 15 notices were returned as undeliverable. Two participants contacted the researcher requesting to be removed from the database, and three programs were identified as closed according to the JRCERT database. E-mail addresses or contacts were verified and corrected and those who previously opted out of Survey Monkey® were asked personally to participate. Of the contacts made, 24 issues were resolved and added back into the database. See Table 4 for a revised population composition.

Table 4: Summary of final population

	Initial contacts	Opt out by request or closure	Opt out of Survey Monkey®	Others returned as undeliverable	Issue resolved (contact corrected/agreed to participate)	Final count
BS	33		(3)	(1)	4	33
AS	390	(1)	(8)	(9)	13	387
Cert	204	(4)	(5)	(2)	7	200
Total	627					620

On April 6, the questionnaire was sent embedded in another e-mail which reinforced the content of the first message. Survey Monkey® automatically tracked responses and was set to send the appropriate follow-up messages according to predetermined time intervals. Thank you messages were sent immediately upon survey completion and included contact information of the researcher for follow up questions or concerns. A reminder email with another embedded link to the survey was sent to non-respondents after ten days. Because the response rate was still inadequate following this reminder, additional reminders were initiated.

To maximize the final response rate, phone contact was attempted for all non-respondents from the BS population, and a random sample of non-respondents from the AS and certificate populations. The majority of contacts resulted in messages left on voice mail, however, among those personal contacts which were successful, all but four responded positively. A final email reminder was sent on April 26 to all non-respondents. This reminder included a statement that the survey would be closed on May 3 to encourage procrastinators to respond.

Research questions and hypotheses

The following research questions and hypotheses were addressed in this study. Data collected were analyzed with both descriptive and inferential statistics using SPSS software.

1. How is critical thinking currently defined by radiologic sciences program directors?
2. How do radiologic science programs teach critical thinking?
3. How do radiologic science programs assess critical thinking?
4. Are there differences in the definition or perceived skills associated with critical thinking between programs taught at different levels (BS, AS and certificate)?

    $H_{\emptyset}$4.1 There are no differences in the definition or perceived skills associated with critical thinking between BS, AS and certificate level programs.

5. Are there differences in the definition or perceived skills associated with critical thinking among program directors with varying levels of academic preparation?

    $H_{\emptyset}$5.1 There are no differences in the definition or perceived skills associated with critical thinking between program directors with masters versus doctoral degrees.

6. Are there differences in reported critical thinking teaching strategies between programs at various educational levels (BS, AS and certificate)?

$H_Ø6.1$ There are no differences in reported critical thinking teaching strategies between BS, AS and certificate level programs.

7. Are there differences in reported critical thinking assessment measures between programs at various educational levels (BS, AS and certificate)?

$H_Ø7.1$ There are no differences in reported critical thinking assessment measures between BS, AS and certificate level programs.

Analyses: Research questions one, two and three, “How is critical thinking currently defined by radiologic sciences program directors?”, “How do radiologic science programs teach critical thinking?” and “How do radiologic science programs assess critical thinking?” were addressed with descriptive statistical analyses using measures of central tendency (mean, median, and standard deviation) of the participants’ responses to survey parts A through D.

Questions four through seven with their corresponding null hypotheses were analyzed using a Kruskal-Wallis (K-W) technique which is the non-parametric equivalent to the one-way analysis of variance (ANOVA). This was performed to demonstrate whether there were differences in the dependent variables of definition or perceived skills involved with critical thinking; and reported critical thinking teaching strategies; and assessment measures used. These differences were analyzed for each independent variable of programmatic academic level and program directors level of academic preparation. The K-W statistic to compare medians was deemed appropriate because the dependent variables in this case were ordinal in nature and the calculated means failed to meet the assumptions of normality and homogeneity of variance needed to obtain accurate ANOVA results (Weinberg & Abramowitz, 2002).

Pair-wise comparisons of significant variables were conducted using the Mann-Whitney U test to identify the degree of significant difference seen between each of the groups.

CHAPTER FOUR: RESULTS

The results of this research study describe the perceptions of radiologic sciences program directors regarding the definition of and skills associated with critical thinking. They also explore whether there are differences in this perception, teaching strategies and assessment measures reported by programs taught at the BS, AS and certificate levels; or by program directors with varying levels of academic preparation. The data are presented in the appendices as indicated in each section.

Response Rate

Of the 620 questionnaires distributed, 295 were completed for a total response rate of 47.6 %. According to the population stratification, the response rate for BS degree programs was 72.7 % (n= 24); for AS degree programs 42.6 % (n= 165); and for certificate programs 53.0 % (n= 106). See Table 5 for summary data.

Table 5: Survey response rates

Program level	# solicited	# responses	Response rate	Margin of Error
BS	33	24	72.7 %	10.61 %
AS	387	165	42.6 %	5.79 %
Certificate	200	106	53.0 %	6.54 %
Total	620	295	47.6 %	4.13 %

Reliability and Validity of Survey Responses

Reliability was assured by applying Cronbach's alpha. Construct validity of the survey instrument was ensured by using Gordon's items as the foundation for the current questionnaire. In addition, the items were further validated by performing an exploratory factor analysis.

Reliability statistics were performed on the survey results for each major scale identified, including perception of *Critical Thinking Definition, Teaching Strategies and Assessment Methods*. Responses to items rating perception of *Critical Thinking Definition* were judged to be very reliable based on a Cronbach's alpha of .899 (N of items = 50). One variable, *critical thinking is best acquired in liberal arts, non-health professions courses*, had a negative correlation. If this item were removed the reliability of the scale would further improve to .902.

Responses to variables related to *Teaching Strategies* (N of items = 28) were also judged to be very reliable with a Cronbach's reliability coefficient of .862. None of the items had a negative correlation. Responses to variables associated with *Assessment Measures* (N of items = 12) were very reliable based on a Cronbach's alpha of .807. None of the items had a negative correlation.

Construct validity was investigated using an exploratory factor analysis which was deemed appropriate since there were greater than 100 responses per item (Thompson, 2004). Separate principal component analyses using promax rotation were conducted on items identified as measuring *Critical Thinking Definition, Teaching Strategies* and *Assessment Measures* to extract factors from the variable data. For the scale measuring *Critical Thinking Definition*, Bartlett's Test of Sphericity was significant with χ^2 (1225, N = 50) = 4205.3, $p < .01$; and a large

Kaiser-Meyer-Olkin measure (.810). Using Kaiser's rule of retaining only those factors whose eigenvalues are greater than 1.0, 14 factors were found to explain 67.25 % of all the item variance and were extracted. For the scale measuring *Teaching Strategies*, Bartlett's Test of Sphericity was significant with χ^2 (91, N = 14) = 825.2, p < .01; and a large Kaiser-Meyer-Olkin measure (.788). Four factors were found to explain 58.57 % of all the item variance and were extracted. For the scale measuring *Assessment Measures*, Bartlett's Test of Sphericity was significant with χ2 (66, N = 12) = 979.2, p < .01; and a large Kaiser-Meyer-Olkin measure (.747). Three factors were found to explain 62.4 % of all the item variance and were extracted.

Demographic Characteristics of Respondents

Part E of the questionnaire contained eight items; two of which were applied as independent variables in the statistical analyses. The other six were included to establish a broader view of the respondents' characteristics which served to more accurately describe similarities and differences in the respondents' backgrounds or educational cultures and may prove relevant in future research studies. The demographic items included were:

- Type of organization sponsoring the program
- Terminal degree awarded to graduates of the program
- Program size as measured by enrollment of first year students
- How the respondent developed his/her own perception of critical thinking
- Highest level of completed academic preparation
- Professional credentials

- Years of experience as radiologic science educator
- Years of experience in radiographic professional practice

Program Characteristics

Surveys were distributed and tracked according to the database provided by the Joint Review Committee on Education in Radiologic Technology (JRCERT) which listed programs according to academic level. The distribution of responses however, deviated from the original database as several programs reported different terminal degrees awarded to their graduates as compared to the level recognized by the accrediting agency. Open responses commenting on this variable indicated that there are many affiliations between programs and academic institutions which provide additional opportunities for graduates to matriculate and complete degree requirements which supersede those of the basic program level. The majority (55.0 %) of responding programs (n = 148) indicated they award the AS degree; certificate/diploma programs comprised 29 % (n = 78) and BS degrees were awarded by 11.5 % (n = 31) of programs in the sample. A summary of reported terminal degrees is included in Table 6.

Program Director Characteristics

The questionnaire was distributed to program directors of accredited radiography programs. The JRCERT standards require that program directors possess at least a master's degree in addition to the appropriate professional credentials. Ninety – seven percent (n= 263) of respondents reported meeting or exceeding this requirement. Eighty-seven percent (n= 235) reported an earned master's degree. Reported areas of academic study were predominately related to education, followed by business and imaging or other science related fields. There were still a small number (n=7) or three percent of program directors holding only a bachelor's degree. It was assumed that these represent individuals who are either currently pursuing the master's degree or are in the process of retiring or otherwise transient in their positions. There are increasing numbers of educators pursuing advanced degrees. Results showed that 10.3 % (n = 28) hold earned doctorates. Like those with master's degrees, the majority reported education as their area of academic study.

Table 6: Demographic characteristics of respondents

		Program Director Academic Preparation		
Program Academic Level		*Baccalaureate	Masters	Doctoral
BS	n = 31 % of total = 11.5	1	21	9
AS	n = 148 % of total = 55	6	127	15
Certificate	n = 78 % of total = 29	0	74	4
Other		0	12	0
Total		7	234	28

Note: JRCERT standards require a minimum of a master's degree for all program directors

Almost all (99.3 %) of the respondents (n = 269) reported professional credentials in radiography. The most commonly reported additional credentials held included 24.7 % in Mammography (n = 67), 15.1 % in Computed Tomography (n = 41), and 9.2 % in Quality Management (n = 25).

Respondent Development of Personal Perception of Critical Thinking

Because critical thinking has not been previously defined for health professions education, evaluation of how individual educators obtained their personal perception of the construct was thought to be an important factor. Table 7 summarizes how faculty developed their perception of the construct of critical thinking. Respondents were instructed to choose all that apply resulting in multiple selections by each. Formal coursework in graduate school was a factor in how 63.4 % (n = 173) reported that they attained an understanding of critical thinking, and attendance at conferences and workshops on critical thinking (n = 196) was cited by 71.8 %. Informal discussions with other health professions faculty (n = 211) accounted for 77.3 %, informal discussions with non-health professions faculty (n = 107) was used by 39.2 %, and reading professional journals (n = 182) was indicated by 66.7 %. Written responses highlighted other methods which were not included in the item choices on the questionnaire but were considered significant factors. These methods included professional and personal research on critical thinking, developing critical thinking curricula, years of experience and observation in the field, general life experiences, and educational preparation. Comments highlighted the magnitude of self-directed learning opportunities pursued by respondents to expand their understanding of the construct in order to better teach and assess it in their students.

Table 7: Development of personal perception of critical thinking

Method used to develop personal perception of critical thinking		Number of Respondents (n)	Percent of Respondents (%)
Formal coursework in grad school	Doctoral	17	60.7
	Masters	152	65
	Baccalaureate	1	12.5
Informal discussions / HP faculty	Doctoral	24	85.7
	Masters	179	76.5
	Baccalaureate	6	75
Informal discussions/non-HP faculty	Doctoral	14	50
	Masters	86	36.8
	Baccalaureate	6	62.5
Conferences/workshops	Doctoral	19	67.9
	Masters	169	72.2
	Baccalaureate	5	62.5
Reading professional journals	Doctoral	19	67.9
	Masters	156	66.7
	Baccalaureate	4	50
Other	Doctoral	4	14.3
	Masters	33	14.1
	Baccalaureate	2	25
Total		270	

Note: Total percent is greater than 100 because of multiple responses.

Incorporation of Critical Thinking in the Curriculum

Item two, part A of the questionnaire asked, “How is critical thinking incorporated into your curriculum?” Respondents were again instructed to choose all that apply resulting in multiple selections by each. These results summarized in Table 8 revealed that only one percent (n = 3) indicated that critical thinking is not specifically addressed and conversely that 7.2 % (n= 21) stated that a specific course in critical thinking skills is included in the program. The majority (n = 275; 93.9 %) of directors indicated that they teach critical thinking by integrating instruction in lecture classes and clinical courses (n = 274; 93.5 %) and into lab assignments (n = 266; 90.8 %). Other methods of incorporating critical thinking that did not meet the criteria of any of the choices provided were reported in the free response section and included service learning projects and a general focus on thinking rather than memorization throughout the entire curriculum.

Table 8: Incorporation of critical thinking into Curriculum

Method	Number of Respondents (n)	Percent of Respondents (%)
Not specifically addressed	3	1.0
Separate course in critical thinking	21	7.2
Integrated into lecture courses	275	93.9
Integrated into clinical courses	274	93.5
Integrated into lab assignments	266	90.8
Other	24	8.2

Note: Total percent is greater than 100 because of multiple responses.

Item three, part A asked "Which courses in the curriculum provide an opportunity for students to increase their critical thinking skills?" The results, summarized in Table 9 revealed that critical thinking skills are integrated across the entire curriculum for many programs with the highest concentration across *Patient Care* (n = 235; 80.2 %), *Radiographic Procedures* (n = 265; 90.4 %), and *Radiographic Exposures & Technique* (n = 255; 87.0 %) courses and labs. Other courses identified which were not included in the choices on the questionnaire included *Clinical courses, Quality Assurance, Image Analysis, Advanced Imaging, Ethics and Medical Law, Leadership, Research* and *Radiographic Pathology.*

Table 9: Courses with critical thinking focus

Course	Number of Respondents (n)	Percent of Respondents (%)
Radiographic Procedures	265	90.4
Procedures lab	265	90.4
Radiographic Exposure & Technique	255	87.0
Patient Care	235	80.2
Exposures labs	207	70.6
Radiation Biology & Protection	167	57.0
Radiation Physics	145	49.5
Introduction to Radiologic Sciences	128	43.7
Physics labs	96	32.8
Other	36	12.3

Note: Total percent is greater than 100 because of multiple responses.

Research Question Analysis

These results are presented in seven sections corresponding to the proposed research questions and hypotheses. Summary data for each section are included in the appendices as noted. Agreement with each item was acknowledged when respondents selected either agree or strongly agree, and was indicated numerically when the median was calculated as either 4 or 5 and the mean response fell between 3.5 and 5.0. Disagreement was noted when participants responded disagree or strongly disagree and was indicated numerically when the median was calculated as either 1 or 2 and the mean fell between 1.0 and 2.4. A median of 3 or mean responses between 2.5 and 3.4 were interpreted as neither agree nor disagree.

Research Question One

How is critical thinking currently defined by radiologic sciences program directors?

This question was addressed by evaluating items from parts A and D on the survey tool in which perceived definitions of critical thinking were classified into two dimensions; *General statements regarding critical thinking in radiologic science,* and *critical thinking attributes*. A complete summary of the descriptive statistics are included in appendix G.

For the general critical thinking items in part A, there was widespread and strong agreement that *critical thinking is a vital skill* (n = 272; m = 4.83; s.d. = .395) *which must be included in radiologic science educational programs* (n = 272); m = 4.69; s.d. = .565). This was expected, since critical thinking is included as a required programmatic outcome for JRCERT accreditation. The respondents also generally agreed that *critical thinking is a generalizable skill* (n = 271; m = 4.30; s.d. = .737) which *can be learned* (n = 271; m = 4.02; s.d. = .647). Interestingly, the level of agreement was not as strong for the *need of a standard model or definition for critical thinking in radiologic sciences* (n = 271; m = 3.79; s.d. = .924); or that *programs do a good job teaching critical thinking* (n = 269; m = 3.68; s.d. = .848), and that *their own graduates have well developed critical thinking skills upon entering the job market* (n = 272; m = 3.87; s.d. = .650). There was moderate agreement that *critical thinking is a rational process* (n = 267; m = 3.88; s.d. = .769) and *synonymous with decision making* (n = 270; m = 3.64; s.d. = .945), and *problem solving* (n = 269; m = 3.81; s.d. = .896).

There was neither agreement nor disagreement (n = 271) that *clinical reasoning is synonymous with critical thinking* (m = 3.36; s.d. = .979). There was also not a clear consensus regarding the statement that *critical thinking in radiography may be conceptually different than critical thinking in other health care disciplines* (n = 269; m = 3.13; s.d. = 1.68), and *a critical thinker in radiography may not be a critical thinker in other areas* (n = 269; m = 3.08; s.d. = 1.04).

Respondents indicated clear disagreement with the statement that *critical thinking is synonymous with following protocols* (n = 271; m = 2.05; s.d. = .879) and also that *critical thinking is best acquired in liberal arts, non-health professions courses* (n = 271; m = 1.70; s.d. = .706).

Part D of the questionnaire contained items describing critical thinking attributes. Many of these were very similar to items in part A; however the responses were not always consistent. Consistent with part A, respondents indicated continued agreement that *problem solving* (n =

269; m = 4.39; s.d. = .567) is an attribute of critical thinking; and continued disagreement that *following protocols* (n = 266; m = 2.75; s.d. = .994) is an attribute. Attributes for which the respondents neither agreed nor disagreed included: *performing routine procedures* (n = 268; m = 3.05; s.d. = 1.057), *empathizing* (n = 268; m = 2.82; s.d. = 1.03), *sensing* (n = 267; m = 3.41; s.d. = .974), *speaking or writing* (n = 265; m = 3.43; s.d. = .919), *motivating others* (n = 269; m = 3.42; s.d. = .953), *managing others* (n = 268; m = 3.53; s.d. = .909), and *reading* (n = 269; m = 3.27; s.d. = .956).

Contrary to the results from part A which indicated a lack of general agreement that clinical reasoning is synonymous with critical thinking, respondents indicated relatively strong agreement regarding many attributes which are supported in the literature as components of clinical reasoning (DiVito-Thomas, 2000; N. C. Facione & Facione, 2008), including: *deductive reasoning* (n = 270; m = 4.19; s.d. = .585), *inductive reasoning* (n = 268; m = 4.06; s.d. = .625), *using clinical judgment* (n = 270; m = 4.40; s.d. = .587), *judging evidence to be more or less important* (n = 269; m = 4.0; s.d. = .706), *thinking creatively* (n = 270; m = 4.13; s.d. = .702), *using higher cognitive thinking* (n = 267; m = 4.24; s.d. = .652), *exploring ethical issues* (n = 264; m = 4.19; s.d. = .660), *exercising reflective reasoning* (n = 270; m = 4.05; s.d. = .693), *adapting protocols based on clinical situations* (n = 267; m = 4.33; s.d. = .635), and *reasoning to make clinical decisions* (n = 270; m = 4.47; s.d. = .515).

General, albeit less robust agreement, was reported for attributes such as *planning* (n = 266; m = 3.72; s.d. = .863), *defending an opinion* (n = 267; m = 3.91; s.d. = .815), *applying reflective skepticism* (n = 267; m = 3.84; s.d. = .703), *interrogating or cross-examining* (n = 269;

m = 3.68; s.d. = .856), *communicating verbally* (n = 268; m = 3.54; s.d. = .984), *interpreting data on a table or graph* (n = 268; m = 3.65; s.d. = .846), *reasoning intuitively* (n = 267; m = 3.87; s.d. = .868), *conducting research in a discipline* (n = 268; m = 3.66; s.d. = .895), *implementing a plan* (n = 267; m = 3.69; s.d. = .878), *thinking about thinking* (n = 268; m = 3.69; s.d. = .841), *recognizing cues* (n = 269; m = 3.83; s.d. = .826), and *judging the credibility of a source* (n = 269; m = 3.91; s.d. = .756).

Research Question Two

How do radiologic science programs teach critical thinking?

This question was addressed by evaluating items from part B on the survey tool which was divided into two sections. The first section contained a list of teaching strategies and asked the extent to which respondents agreed whether the listed activities are actually effective for developing critical thinking in students. The second section subsequently asked the respondents to indicate the percentage of their curriculum which uses each of the strategies. A complete summary of the descriptive statistics is included in appendix G.

Teaching strategies recognized as effective by program directors were identified by the level of agreement of respondents. There was strong agreement that *in-class discussions* (n = 271; m = 4.29; s.d. = .558), *clinical case studies* (n = 270; m = 4.36; s.d. = .616), *situational judgment test items* (n = 269; m = 4.34; s.d. = .561), *role playing* (n = 271; m = 4.20; s.d. = .727), *collaborative learning* (n = 268; m = 4.09; s.d. = .711), *case based learning* (n = 267; m = 4.19; s.d. = .688), and *problem based learning* (n = 270; m = 4.35; s.d. = .577) were all effective strategies for teaching critical thinking. Moderate agreement was also indicated for *Socratic questioning* (n = 267; m = 3.74; s.d. = .797), *reflective journaling* (n = 269; m = 3.77; s.d. = .836), *concept mapping* (n = 266; m = 3.71; s.d. = .764), and *higher-order multiple choice test items* (n = 270; m = 3.95; s.d. = .750). There was neither agreement nor disagreement regarding the effectiveness of *on-line discussions* (n = 265; m = 3.44; s.d. = .860), *traditional lectures* (n = 269; m = 3.26; s.d. = .985), and *portfolios* (n = 257; m = 3.32; s.d. = .905).

Actual utilization of these strategies was considered by evaluating responses indicating the percentage of the curriculum in which each strategy is used. High utilization was indicated by median scores of either 5 (50% – 74 %) or 6 (75% – 100%) and a mean score of 4.5 – 6.0, moderate utilization was indicated by a median score of 4 (25% – 49 %) and a mean score of 3.5 – 4.4, and low utilization was indicated by median scores of 3 (10% – 24 %), 2 (less than 10 %) or 1 (never) and a mean score of 1.0 – 3.4. A comparative summary of assumed effectiveness and actual utilization is included in Table 10.

It was noted that the most highly used teaching strategies included *traditional lectures* (n = 264; m = 4.80; s.d. = 1.16), *in-class discussions* (n = 264; m = 4.72; s.d. = 1.16), and *higher-order multiple choice test items* (n = 260; m = 4.70; s.d. = 1.24). Those used moderately included *clinical case studies* (n = 263; m = 3.96; s.d. = 1.27), *situational judgment test items* (n = 266; m = 3.77; s.d. = 1.41), *problem based learning* (n = 265; m = 3.98; s.d. = 1.35), *case-based learning* (n = 261; m = 3.49; s.d. = 1.37), and *collaborative learning* (n = 262; m = 3.85; s.d. = 1.41). Low utilization was indicated for *Socratic questioning* (n = 222; m = 3.37; s.d. = 1.46), *on-line discussions* (n = 262; m = 2.06; s.d. = 1.22), *reflective journaling* (n = 259; m =

2.54; s.d. = 1.43), *concept mapping* (n = 251; m = 2.27; s.d. = 1.43), *role playing* (n = 266; m = 3.39; s.d. = 1.51), and *portfolios* (n = 252; m = 2.15; s.d. = 1.44).

Table 10: Teaching strategies - Effective vs. actual utilization

Teaching Strategy	Effective for instruction	Utilization in curriculum
In-class discussion	Strongly agree	High
Clinical case studies	Strongly agree	Moderate
Situational-judgment test items	Strongly agree	Moderate
Case-based learning	Strongly agree	Moderate
Problem-based learning	Strongly agree	Moderate
Collaborative learning	Strongly agree	Moderate
Role playing	Strongly agree	Low
High-order multiple choice test items	Agree	High
Reflective journaling	Agree	Low
Concept mapping	Agree	Low
Socratic questioning	Agree	Low
Traditional lecture	Neither agree nor disagree	High
On-line discussion	Neither agree nor disagree	Low
Portfolios	Neither agree nor disagree	Low

Research Question Three

How do radiologic science programs assess critical thinking?

This question was addressed by evaluating items from part C on the survey tool which was divided into two sections. The first section contained a list of assessment measures and asked the extent to which respondents agreed whether the listed measures are considered appropriate for measuring critical thinking used by students. The second section asked the respondents to indicate which of the listed measures they report to the JRCERT to document critical thinking as a programmatic learning outcome. A complete summary of the descriptive statistics is included in appendix G.

Respondents indicated strong agreement regarding the appropriateness of *clinical competency results* (n = 272; m = 4.34; s.d. = .687), *image critique performance* (n = 271; m = 4.36; s.d. = .585), *specific course assignments* (n = 270; m = 4.03; s.d. = .703), *situational judgment test items* (n = 271; m = 4.20; s.d. = .606), and *clinical case studies* (n = 268; m = 4.11; s.d. = .659), as tools to assess critical thinking. Moderate agreement was also observed for *course exam results* (n = 269; m = 3.56; s.d. = .894), *ARRT exam results* (n = 271; m = 3.36; s.d. = 1.02), *portfolios* (n = 267; m = 3.03; s.d. = .979), *reflective journals* (n = 267; m = 3.35; s.d. = .978), *employer surveys* (n = 271; m = 3.46; s.d. = .953), *student surveys* (n = 271; m = 3.39; s.d. = .951), and *standardized critical thinking tests* (n = 259; m = 2.93; s.d. = .731).

Programmatic learning outcomes for critical thinking reported to the JRCERT were identified by respondents in the second section of part C on the survey tool. The instructions were to choose all that apply. The measures selected by at least 50 percent of the respondents (n = 274) were *clinical competency results* (n = 221; 80.7 %), *employer surveys* (n = 187; 68.2 %), *image critique performance* (n = 182; 66.4 %), *specific course assignments* (n = 164; 59.9 %), *student surveys* (n = 151; 55.1 %), and *ARRT exam results* (n = 137; 50.0 %). The measures selected least were *standardized critical thinking tests* (n = 7; 2.6 %), *portfolios* (n = 37; 13.5 %), and *reflective journals* (n = 38; 13.9 %).

Research Question Four

Are there differences in the definition or perceived skills associated with critical thinking between programs taught at different levels (BS, AS and certificate)?

$H_Ø$ 4.1 There are no differences in the definition or perceived skills associated with critical thinking between BS, AS and certificate level programs.

Part A of the questionnaire contained statements linked to general critical thinking concepts and how they relate to radiologic sciences. Program directors were instructed to indicate the degree to which they agreed or disagreed with each statement. Part D of the questionnaire contained a list of critical thinking attributes and program directors were asked to indicate the degree to which they agreed or disagreed that each attribute was considered the same as critical thinking. A chi square analysis using the Kruskal-Wallis method was conducted to demonstrate differences in the population medians between the three academic levels of radiologic science programs. Cramer's V statistics were calculated to reveal the strength of association between those variables found to exhibit significant differences. The results with estimated effect sizes are included in appendix H.

Results of this analysis showed that three variables from part A and two variables from part D revealed significant differences at an alpha of 0.05. Data analyses for the significant items are included in Table 11.

Table 11: Significant results –Critical thinking definition by program level

			Ranks	**Kruskal - Wallis**			**Effect size**
Part A	Program level	n	Mean Rank	Chi-square	df	p	Cramer's V
A critical thinker in radiography may not be a critical thinker in other (non-health care)areas or activities	Certificate/diploma	82	147.15	7.783	2	.020	.161
	Associate degree	153	135.20				
	Bachelors degree	34	104.82				
	Total	269					
Critical thinking and following protocol are synonymous	Certificate/diploma	84	129.11	7.483	2	.024	.159
	Associate degree	153	145.24				
	Bachelors degree	34	111.46				
	Total	271					
Critical thinking is best acquired in liberal arts, non health professions courses	Certificate/diploma	83	149.85	6.866	2	.032	.148
	Associate degree	154	133.40				
	Bachelors degree	34	113.99				
	Total	271					
Part D							
Following protocols	Certificate/diploma	84	146.81	6.556	2	.038	.131
	Associate degree	148	131.49				
	Bachelors degree	34	109.38				
	Total	266					
Implementing a plan	Certificate/diploma	84	142.70	8.802	2	.012	.115
	Associate degree	149	136.53				
	Bachelors degree	34	101.43				
	Total	267					

Further pair-wise analyses were conducted using the Mann-Whitney U test to isolate specifically where the differences occurred. Results showed that there was no significant difference between certificate and associate degree programs for any of the items

There was a significant difference between bachelor degree programs and the other two for the statement, *a critical thinker in radiography may not be a critical thinker in other areas or activities* (p = .020). A significant difference was also identified between associate and bachelor's degree programs for the statement *critical thinking and following protocol are synonymous* (p = .024). The strength of these associations (Cramer's V = .16) were extremely weak for both of these variables.

Significant differences were identified between certificate and bachelor's programs for *critical thinking is best acquired in liberal arts, non health professions courses* (p = .032); and between bachelor's degree programs and both associate and certificate programs for *implementing a plan* (p = .012). The strength of these associations (Cramer's V = .16 and .115) were extremely weak for both of these variables. Refer to Table 12 for results of the Mann-Whitney U test.

Table 12: Pair-wise comparison - Critical thinking definition by program level

	Program level	n	Mean Rank	Sum of Ranks	Mann-Whitney U	Wilcoxon W	Z	p
A critical thinker in radiography may not be a critical thinker in other (non-health care)areas or activities	Certificate	82	124.87	10239.00	5710.000	17491.000	-1.188	.235
	Associate	153	114.32	17491.00				
	Total	235						
	Certificate	82	63.78	5230.00	961.000	1556.000	-2.749	.006
	Bachelors	34	45.76	1556.00				
	Total	116						
	Associate	153	97.88	14975.00	2008.000	2603.000	-2.167	.030
	Bachelors	34	76.56	2603.00				
	Total	187						
Critical thinking and following protocol are synonymous	Certificate	84	109.66	9211.50	5641.500	9211.500	-1.727	.084
	Associate	153	124.13	18991.50				
	Total	237						
	Certificate	84	61.95	5204.00	1222.000	1817.000	-1.384	.166
	Bachelors	34	53.44	1817.00				
	Total	118						
	Associate	153	98.11	15010.50	1972.500	2567.500	-2.399	.016
	Bachelors	34	75.51	2567.50				
	Total	187						
Critical thinking is best acquired in liberal arts, non health professions courses	Certificate	83	128.29	10648.00	5620.000	17555.000	-1.720	.085
	Associate	154	113.99	17555.00				
	Total	237						
	Certificate	83	63.56	5275.50	1032.500	1627.500	-2.573	.010
	Bachelors	34	47.87	1627.50				
	Total	117						
	Associate	154	96.90	14923.00	2248.000	2843.000	-1.443	.149
	Bachelors	34	83.62	2843.00				
	Total	188						
Following protocols	Certificate	84	124.79	10482.50	5519.500	16545.500	-1.483	.138
	Associate	148	111.79	16545.50				
	Total	232						
	Certificate	84	64.52	5419.50	1006.500	1601.500	-2.656	.008
	Bachelors	34	47.10	1601.50				
	Total	118						
	Associate	148	94.19	13940.50	2117.500	2712.500	-1.507	.132
	Bachelors	34	79.78	2712.50				

	Program level	n	Mean Rank	Sum of Ranks	Mann-Whitney U	Wilcoxon W	Z	p
	Total	182						
Implementing a plan	Certificate	84	120.44	10117.00	5969.000	17144.000	-.650	.516
	Associate	149	115.06	17144.00				
	Total	233						
	Certificate	84	64.76	5439.50	986.500	1581.500	-2.894	.004
	Bachelors	34	46.51	1581.50				
	Total	118						
	Associate	149	96.47	14374.00	1867.000	2462.000	-2.597	.009
	Bachelors	34	72.41	2462.00				
	Total	183						

Research Question Five

Are there differences in the definition or perceived skills associated with critical thinking among program directors with varying levels of academic preparation?

$H_Ø$ 5.1 There are no differences in the definition or perceived skills associated with critical thinking between program directors with masters versus doctoral degrees.

A chi square analysis using the Kruskal-Wallis method was conducted to demonstrate differences in the population medians between the three groups of program directors defined by the highest level of academic preparation achieved. Cramer's V statistics were calculated to reveal the strength of association between those variables found to exhibit significant differences. The results with estimated effect sizes are included in appendix H.

This analysis showed that only one variable from part A showed a significant difference in agreement between program directors with varying levels of academic preparation at an alpha of 0.05. There were no variables from part D that were significantly different. Further pair-wise analyses were conducted using the Mann-Whitney U test to isolate specifically where the differences occurred. Data analyses for the significant item are included in Table 13.

Results showed that there was no significant difference in agreement between program directors with doctoral and masters degrees (p = .040). There was significance between program directors with bachelor degrees and those with doctoral and masters degrees. The strength of this association (Cramer's V = .152) was moderately weak for this variable. Refer to Table 14 for results of the Mann-Whitney U test.

Table 13: Significant results - Critical thinking definition by highest degree

			Ranks	**Kruskal - Wallis**			**Effect size**
	Highest degree	n	Mean Rank	Chi-square	df	p	Cramer's V
Graduates of your program have well-developed critical thinking skills when entering their first radiography job	Doctoral	30	133.60	6.447	2	.040	.152
	Masters	233	138.30				
	Bachelors	8	77.94				
	Total	271					

Table 14: Pair-wise comparison - Critical thinking definition by highest degree

	Highest degree	n	Mean Rank	Sum of Ranks	Mann-Whitney U	Wilcoxon W	Z	p
Graduates of your program have well-developed critical thinking skills when entering their first radiography job	Doctors	30	127.80	3834.00	3369.000	3834.000	-.382	.702
	Masters	233	132.54	30882.00				
	Total	263						
	Doctors	30	21.30	639.00	66.000	102.000	-2.325	.020
	Bachelors	8	12.75	102.00				
	Total	38						
	Masters	233	122.76	28603.50	521.500	557.500	-2.479	.013
	Bachelors	8	69.69	557.50				
	Total	241						

Research Question Six

Are there differences in reported critical thinking teaching strategies between programs at various educational levels (BS, AS and certificate)?

$H_{Ø}$ 6.1 There are no differences in reported critical thinking teaching strategies between BS, AS and certificate level programs.

Part B of the questionnaire contained a list of commonly used teaching strategies. Program directors were instructed to indicate the degree to which they agreed or disagreed that each is effective for developing critical thinking. The second portion of part B, instructed the respondents to indicate the percent of their curriculum which utilizes each of the strategies. A chi square analysis using the Kruskal-Wallis method was conducted to demonstrate differences in utilization in the population medians of teaching strategies between the three academic levels of radiologic science programs. Cramer's V statistics were calculated to reveal the strength of association between those variables found to exhibit significant differences. These results with estimated effect sizes are included in appendix H.

Results of this analysis showed that two teaching strategies showed significantly different levels of utilization of at an alpha of 0.05. The strength of association (Cramer's V = .271) was relatively weak for *Socratic questioning* (p = .034); and moderate (.444) for *on-line discussions* (p = .000). Data analyses for these significant items are included in Table 15.

Table 15: Significant results- Teaching strategy utilization by program level

			Ranks	**Kruskal-Wallis**			**Effect size**
	Program level	n	Mean Rank	Chi-square	df	p	Cramer's V
Socratic questioning	Certificate/diploma	70	99.84	6.763	2	.034	.271
	Associate degree	125	112.59				
	Bachelors degree	27	136.67				
	Total	222					
On-line discussions	Certificate/diploma	84	90.51	40.824	2	.000	.444
	Associate degree	145	149.18				
	Bachelors degree	33	158.14				
	Total	262					

Pair-wise analyses were conducted using the Mann-Whitney U test to isolate specifically where the differences occurred. Results for the teaching strategy, *Socratic questioning* showed that there was no significant difference between certificate and associate degree programs, or between associate and bachelor's programs. There was significance, however between certificate and bachelor's programs. There was also significance between certificate and both associate and bachelor's degree programs for *on-line discussions*. Refer to Table 16 for results of the Mann-Whitney U test.

Table 16: Pair-wise comparison - Teaching strategy utilization by program level

	Program level	n	Mean Rank	Sum of Ranks	Mann-Whitney U	Wilcoxon W	Z	p
Socratic questioning	Certificate	70	90.42	6329.50	3844.500	6329.500	-1.435	.151
	Associate	125	102.24	12780.50				
	Total	195						
	Certificate	70	44.92	3144.50	659.500	3144.500	-2.344	.019
	Bachelors	27	59.57	1608.50				
	Total	97						
	Associate	125	73.35	9168.50	1293.500	9168.500	-1.940	.052
	Bachelors	27	91.09	2459.50				
	Total	152						
On-line discussions	Certificate	84	82.36	6918.00	3348.000	6918.000	-6.037	.000
	Associate	145	133.91	19417.00				
	Total	229						
	Certificate	84	50.65	4255.00	685.000	4255.000	-4.774	.000
	Bachelors	33	80.24	2648.00				
	Total	117						
	Associate	145	88.27	12799.50	2214.500	12799.500	-.694	.488
	Bachelors	33	94.89	3131.50				
	Total	178						

Research Question Seven

Are there differences in reported critical thinking assessment measures between programs at various educational levels (BS, AS and certificate)?

$H_Ø$ 7.1 There are no differences in reported critical thinking assessment measures between BS, AS and certificate level programs.

Part C of the questionnaire contained a list of commonly used assessment measures. Program directors were instructed to indicate the degree to which they agreed or disagreed that each is appropriate for measuring critical thinking. The second portion of part C included the same list and instructed the respondents to indicate which measures they submit to the JRCERT to document critical thinking as a programmatic learning outcome by choosing all that apply. The items were recoded as dichotomous variables based on selection by the respondents. A chi square analysis was conducted using the Kruskal-Wallis method to demonstrate differences in selection of assessment measures between the three academic levels of radiologic science programs. Cramer's V statistics were calculated to reveal the strength of association between those variables found to exhibit significant differences. These results with estimated effect sizes are included in appendix H. Significant differences of reported assessment measures between different program levels were identified for only one variable at an alpha of 0.05 and are included in Table 17. Results of this analysis showed that utilization of *employer surveys* (p = .044) was different according to program level. The strength of association (Cramer's V = .152) was relatively weak.

Table 17: Significant results - Assessment measures utilization by program level

			Ranks	**Kruskal-Wallis**			**Effect size**
	Program level	N	Mean Rank	Chi-Square	df	p	Cramer's V
Employer surveys	Certificate/diploma	85	150.38	6.268	2	.044	.152
	Associate degree	155	134.15				
	Bachelors degree	34	120.56				
	Total	274					

Pair-wise analyses were conducted using the Mann-Whitney U test to isolate specifically where the differences occurred. Refer to Table 18 for results of the pair-wise comparisons.

Table 18: Pair-wise comparison - Assessment measures utilization by program level

	Program level	n	Mean Rank	Sum of Ranks	Mann-Whitney U	Wilcoxon W	Z	p
Employer surveys	Certificate/diploma	85	63.70	5414.50	1130.500	1725.500	-2.364	.018
	Bachelors degree	34	50.75	1725.50				
	Total	119						
	Certificate/diploma	85	129.68	11022.50	5807.500	17897.500	-1.910	.056
	Associate degree	155	115.47	17897.50				
	Total	240						
	Associate degree	155	96.69	14986.50	2373.500	2968.500	-1.089	.276
	Bachelors degree	34	87.31	2968.50				
	Total	189						

Summary

These results were presented to address each of the research questions sequentially using both descriptive and inferential statistical analyses. Discussion of implications and conclusions relevant to these findings are discussed in the following chapter. Recommendations for further research specific to radiologic sciences are also presented.

CHAPTER FIVE: DISCUSSION

This section discusses each of the three main themes addressed in this study:the perceived definition of critical thinking, critical thinking teaching strategies, and critical thinking assessment measures. This is accomplished by elaboration and reflection on the findings, considering the results of the research questions related to each area. Limitations of the current study as well as implications for the profession and recommendations for future research are also presented.

Introduction

As an emerging profession, radiologic technology certainly meets many of the criteria applied to the definition of a profession, while unfortunately, neglecting some key criteria; most importantly, that of the demonstration of professional autonomy (Yielder & Davis, 2009). The allied health professions including nursing and radiography have traditionally been in roles of subservience, performing procedures which function to support physicians (Sim & Radloff, 2009). Indeed, at one time, not so long ago, nurses were ethically bound to obedience in performing their clinical duties (Levett-Jones & Lathlean, 2009). Nurses have worked tirelessly to develop professionally and now have a higher degree of autonomy to practice alongside the physician, rather than in submission to him/her. Radiographers on the other hand, continue to practice in a protocol driven environment with limited autonomy or ability to make decisions without direct oversight by physicians. This culture discourages critical thinking and is one of the most powerful barriers to radiographer's development of, and engagement in critical thinking; along with the resultant critical reflection and questioning of protocols and the status quo (Sim & Radloff, 2009; Yielder & Davis, 2009). It is with this in mind, that this study strives to discover and strengthen current efforts toward professionalization within radiologic technology.

Perceived definition

There are three research questions and two null hypotheses related to the perceived definition of critical thinking. Research question one states "How is critical thinking currently defined by radiologic sciences program directors?" The findings indicate that there is general agreement among program directors regarding the perception of the definition and skills associated with critical thinking in the radiologic sciences.

The null hypothesis related to research question four states "There are no differences in the definition or perceived skills associated with critical thinking between BS, AS and certificate level programs". Although there is general agreement, because significant differences are identified for four variables, this null hypothesis is rejected at the specified alpha of .05.

The related null hypothesis associated with research question five; "There are no differences in the definition or perceived skills associated with critical thinking between program directors with masters versus doctoral degrees" is not rejected at an alpha of .05. While a significant difference is identified for one variable considering differences between program director highest degree earned, this difference is identified using pair-wise comparison as being between those with bachelor's degrees and those with doctoral degrees. Because only differences between master's and doctoral degrees are included in this research question, the null hypothesis that there are no differences in the definition or perceived skills associated with critical thinking between program directors with masters versus doctoral degrees, is not rejected at the specified alpha of .05.

Consistent with the inclusion of critical thinking as a required programmatic outcome by the JRCERT, ninety-nine percent of program directors agree that *critical thinking is a vital skill for radiographers,* and ninety-seven percent agree that *critical thinking must be included in educational programs*.

Radiologic Science program directors have a broad perception of what critical thinking is. This definition includes many related cognitive processes that are not always classified as attributes of true critical thinking by experts, but in some cases are consistent with definitions and attributes identified as critical thinking by other allied health professions. These common attributes include *creative thinking, decision making, problem solving* and *clinical reasoning* (Gordon, 1995), as well as other higher-order thinking activities such as *reflection, judging* and *reasoning deductively and inductively*.

There is some ambiguity however, evidenced in the definition perceived by inclusion of several items which were actually not considered critical thinking skills by the experts. These items were included on the questionnaire as distracters and yet respondents indicate a range in levels of agreement for many of these items. In general, program directors indicate moderate agreement that *planning, interrogating, communicating verbally,* and *conducting research* are skills associated with critical thinking; and neither agree nor disagree that *empathizing, sensing, writing, reading, managing* and *motivating others* are skills associated with critical thinking. Indeed disagreement is identified for only two of the fifty items pertaining to this theme, which reveals an interesting finding. It is possible that these results may indicate a general underlying confusion regarding the applied definition of critical thinking; or it may indicate that critical thinking within radiologic sciences actually does encompass a broader range of skills and attributes which need to be investigated more thoroughly.

Contrasting the profession's traditional reliance on following protocols, respondents reject the premise that this is an attribute associated with critical thinking. There is, however, consistent and strong agreement that *problem solving, effective judgment* and *decision making while adapting protocols based on the situation at hand* are all considered critical thinking for radiographers. In fact, respondents indicate agreement that all of the items derived from higher order thinking, the nursing process and clinical judgment/reasoning are also components of critical thinking in radiologic science.

Although ninety-one percent agree that *critical thinking is a generalizable skill*, forty-two percent believe *a critical thinker in radiography may not be able to apply those skills in another area or activity*. Only three percent agree that *critical thinking is best acquired in liberal arts, non-health professions courses*. In fact sixty-four percent believe that *radiologic science programs generally do a good job teaching critical thinking* and seventy-seven percent report that *their graduates have well-developed critical thinking skills upon entering their first radiography jobs*.

This then leads to a series of more focused questions. How do radiologic science educators develop their perception of critical thinking? If they do not have a clear understanding of the definition of critical thinking, are they really teaching critical thinking skills? Or are they actually teaching some other equally vital cognitive process that is more appropriately linked to competent clinical practice?

Program directors report that efforts to develop their personal perception of critical thinking include graduate course work. However, a high percentage report attending professional workshops and informal discussions with other health professions faculty as a primary source. This sharing of ideas is beneficial for establishing consistency among the clinical professions, but it may also serve to widen the gap between true critical thinking and the perceived definition of critical thinking as applied to clinical practice.

In summary, while the results of this study do not fully clarify a working definition for critical thinking within radiologic science, they do provide the framework of an initial definition for this important construct. This serves as a foundation upon which further knowledge and clarity can be built.

Teaching Strategies

There are two research questions and one null hypothesis related to teaching strategies used in radiologic science programs. Research question two states "How do radiologic science programs teach critical thinking?" This question is addressed by evaluating the listed teaching strategies from two different perspectives. The first indentifies whether each item is perceived as an effective method for teaching critical thinking, and the second identifies actual utilization of each strategy as reported by the respondents.

There is general agreement regarding the appropriateness of specific teaching strategies also supported by the literature, with the exception of *on-line discussions* and *portfolios*. *On-line discussions* may be a problematic item due to the fact that many programs do not offer courses on-line and therefore are not familiar with this tool. The questionnaire does not differentiate between face to face and on-line modalities. *Portfolios* on the other hand, are supported by the literature but respondents neither agree nor disagree regarding their effectiveness. *Traditional lectures* are not considered effective for the development of critical thinking according to the literature yet respondents again indicate they neither agree nor disagree on their effectiveness.

The other strategies listed are all recognized as effective by program directors and are further differentiated by the level of agreement indicated. There is strong agreement that *in-class discussions, clinical case studies, situational judgment test items, role playing, collaborative learning, case-based* and *problem-based learning* are all effective methods. There is moderate agreement that *Socratic questioning, reflective journaling, concept mapping* and *higher-order multiple choice test items* are effective approaches to the development of critical thinking.

Yet utilization of these same strategies is not consistently reported. There is some disparity between strategies reported as useful for teaching critical thinking and their subsequent level of utilization. A summary of these comparisons is available in Table 10. Only *in-class discussion* is consistent in that it is highly used and respondents strongly agree with its usefulness. Other methods for which there is strong agreement include, *situational judgment test* *items, role playing, collaborative learning,* and *case-based and problem-based learning* all show reported utilization as only moderate or low. For those items in which moderate agreement is indicated regarding effectiveness, actual utilization is reported as low.

In summary, it is noted that the most highly used teaching strategies include *traditional lecture,s* with *in-class discussions* and *higher-order multiple choice test items*. Moderately used strategies include *clinical case studies, case/problem based learning, collaborative learning* and *situational judgment items*. Teaching strategies indicated as effective by the literature, and yet not consistently used in educational programs, include *Socratic questioning, reflective journals, concept mapping, role playing,* and *portfolios*.

This phenomenon may be due to the relatively undeveloped concept of critical thinking held by the respondents, or lack of foundational understanding. The majority of radiologic science faculty currently striving to develop critical thinking in their students were not themselves educated in the principles and skills needed for critical thinking. It may be that an educator's approach to teaching is related to his or her own ability to think critically (Zygmont & Moore-Schaefer, 2006). The link between critical thinking ability and overall cognitive development is beyond the scope of this study, but is certainly an important variable which should be included in future research.

Research question six states, "Are there differences in reported critical thinking teaching strategies between programs at various educational levels (BS, AS and certificate)?" and its corresponding null hypothesis reads, "There are no differences in reported critical thinking teaching strategies between BS, AS and certificate level programs." While there is general agreement for most items evaluated, because significant differences are identified for two variables, this null hypothesis is rejected at the specified alpha of .05. Results indicate that there is a significant difference between utilization of *Socratic questioning* ($p = .019$) between certificate programs and BS programs; and utilization of *on-line discussions* ($p = .000$) between certificate programs and both AS and BS programs.

Upon evaluation of the results, it is suspected that these differences may be attributed to unmeasured variables or unclear items on the questionnaire. It is probable that AS and BS degree programs use on-line course formats more often than certificate programs, which would provide a valid explanation for the difference identified. It is observed that many chose not to respond to the item, *Socratic questioning*. This may be a term that not all educators are familiar with, and since terms were not defined on the questionnaire, it is possible that differences noted in the results are actually attributed to lack of understanding of the item.

Assessment Measures

There are two research questions and one null hypothesis related to critical thinking assessment measures used in radiologic science programs. Research question three states, "How do radiologic science programs assess critical thinking?" This question is addressed by evaluating the listed assessment measures from two different perspectives. The first indentifies whether each item is perceived as an effective method for assessing critical thinking and the second identifies actual utilization of each tool as reported by the respondents.

All of the twelve items included on the questionnaire are identified as appropriate tools for assessing critical thinking as indicated by moderate to strong agreement with each. Strong agreement is indicated for *clinical competency results, image critique performance, specific course assignments, situational judgment test items,* and *clinical case studies*. Moderate agreement is observed for *course exam results, ARRT exam results, portfolios, reflective journals, employer surveys, student surveys* and *standardized critical thinking tests*.

The most highly used assessment measures are identified by at least fifty percent of respondents. These include *clinical competency results, employer surveys, image critique performance, specific course assignments, student surveys* and *ARRT exam results*. The least used are identified by less than fifteen percent of respondents and include *standardized critical thinking tests, portfolios* and *reflective journals*. Assessment measures selected by thirty to forty-six percent of respondents include *course exam results, situational judgment items* and *clinical case studies*.

This study does not address the structure and content of the assessment measures listed and therefore it is not known whether these are in fact measuring critical thinking. It is possible that since radiologic sciences educators may not have fully developed their perception of critical thinking, they may or may not have developed assessment tools which accurately measure this construct. Instead, it is possible that they may have retrospectively gone back to look at their curriculum, decided which components are likely to teach critical thinking, and then reported those as outcome measures to the JRCERT. In many cases, depending on the program director's understanding of critical thinking, learning outcomes have been developed and assignments tweaked somewhat, but substantive changes to the curriculum to address critical thinking may not have been incorporated. Further research is needed to fully explore exactly what is being assessed and how these assessments are conducted. This in turn will illuminate how well the profession is addressing critical thinking, while bringing radiologic sciences in line with other health professions.

Research question seven states, "Are there differences in reported critical thinking assessment measures between programs at various educational levels (BS, AS and certificate)?" and its corresponding null hypothesis reads, "There are no differences in reported critical thinking assessment measures between BS, AS and certificate level programs." There is general agreement for most items evaluated, however because significant differences are identified for one variable, this null hypothesis is rejected at the specified alpha of .05. Results indicate that there is a significant difference ($p = .018$) between utilization of employer surveys between certificate programs and BS programs; and a marginal difference ($p = .056$) between certificate programs and both AS and BS programs. There is no statistically significant difference ($p = .276$) between AS and BS degree programs.

Limitations

Results of these statistical analyses should be interpreted with caution since even though significant differences were observed for a few items within each theme, the calculated effect sizes for all parameters was extremely small, indicating a high likelihood of Type II error. This was due in part to a significant imbalance in the sizes of the sub-populations; and despite attempts made to maximize response rates, less than 50 percent of program directors chose to participate, making statistical comparisons less robust. The timing of this research likely contributed to the lower than desired response rate. All solicitations were sent in April which is typically a difficult time for faculty to be reached. With each distribution of contact letters, multiple "out-of-the-office" replies were received indicating many were on leave for spring break or attending conferences. These disruptions in communication along with the general busyness of this time in the academic term may have discouraged many from completing the questionnaire.

Failure to clearly define constructs and terminology used on the questionnaire may have resulted in variability in interpretation by the respondents. This variability is immeasurable but may have influenced the validity of the results.

Implications

If radiologic science personnel are serious about gaining recognition as a profession, they must take ownership of their own research agenda and proactively address issues affecting educational standards and clinical practice. They should not be afraid to rely on their own professional knowledge and experience nor should they defer to other disciplines with stronger research backgrounds. Those intimately involved in radiographic practice are the most adept at addressing professional issues.

Critical thinking is one of these vital issues. Professionals and educators need to work together to establish precisely what critical thinking looks like in radiographic practice. This should form the basis for a working definition of critical thinking which can be broken down into discreet parts. And these parts then could be used to develop learning objectives to be used in the educational process. A preliminary definition of critical thinking developed by the researcher in response to the results of this study is:

> The affective and cognitive skills used during clinical practice to make sound decisions and judgments while adapting protocols to provide creative solutions to difficult patient situations.

This definition should be used as a springboard to more fully develop a working definition and identify specific affective traits and cognitive abilities needed for critical thinking. Once this is established, then work should continue to develop practical applications related to effective teaching strategies and appropriate assessment measures.

The JRCERT requirement for program directors to obtain advanced degrees has increased the overall educational preparation of radiography educators in general. The vast majority of program directors have earned at least a master's degree, and many more are pursuing doctoral degrees. Additionally, there is a trend to elevate certificate level programs to at least the AS degree level, resulting in increasing numbers of affiliations between hospital based programs and academic institutions. This is changing the characteristics of programs and faculty with subsequent strengthening of the academic culture. This may in turn lead to an increased understanding of critical thinking as well as appropriate teaching strategies and assessment measures; and the propensity to address these topics as vital professional issues.

Recommendations

Based on the results of this study, the main recommendations are to continue research in order to develop a working definition of what critical thinking looks like in radiologic science. Because this study suggests that the respondents' perceptions of critical thinking are congruent with definitions perceived by other clinical professions, new research should be informed by valid research already in progress across other allied health professions such as nursing.

The JRCERT and other professional organizations must proactively establish opportunities for conversation and collaboration to expedite this process. The ASRT and AEIRS should take the lead to provide forums for the establishment of consensus between educators, clinicians and other leaders in the profession regarding how critical thinking is exhibited in clinical practice. A Delphi study similar to those reported by Facione (1990) and Scheffer & Rubenfeld (2000) might be the most effective process to come to consensus and offer valuable insight to others working in the profession.

As the standard bearer, the JRCERT should disseminate the findings and also provide direct guidance to accredited programs. They need to embrace this role and clarify definitions of constructs used in the *Standard*s in a way that promotes consistency across the profession.

Additional focused research is also needed to more clearly describe assessment measures currently being reported to the JRCERT since this study does not attempt to determine whether these are actually appropriate. Deeper inquiry should be made to accomplish this goal since there is no guarantee that what programs are now reporting really measures critical thinking.

Finally, research is needed to determine the effectiveness of teaching strategies currently in use, as well as those recommended for the development of critical thinking. Because critical thinking is most likely discipline specific, then teaching strategies should be designed to address the knowledge and competencies needed by professional radiographers.

Summary

Research studies continue to yield mixed results regarding the effectiveness of current efforts to develop critical thinking in allied health fields across the educational and professional continuum. This study does little to provide increased clarity, although it certainly plays a part in establishing an excellent starting point for continued research. The foundational construct for critical thinking in radiologic science remains incomplete although attention to this issue is increasing among educators. Continued effort is imperative to bring a level of consistency to application and assessment of professional practice standards. Over the course of this study, the researcher received numerous contacts and comments from other educators who are actively pursuing this issue. These efforts will certainly yield positive progress toward the establishment of a clear definition and practical applications to develop critical thinking within the imaging profession.

On the other hand, it should also be considered that perhaps the continued struggles to arrive at a consensus definition for critical thinking, to demonstrate the effectiveness of teaching strategies, and to develop valid assessment tools are indications that critical thinking in health professions is inherently different than critical thinking in other non-health professions. It may not be appropriate to try to address it in the same way. Indeed, an interesting prospect comes to mind that it may be time to abandon these attempts to make critical thinking fit into professional practice, and instead step back, identify exactly which cognitive skills and dispositions are desired for competent clinical practice, and then proceed to teach and assess them accordingly.

Questions such as these may only be resolved through continued research and focused efforts by educators and clinicians. Radiographers must be prepared and willing to think critically about critical thinking to find effective practices and advance radiologic technology toward increased professionalization.

APPENDIX A
PERMISSION LETTER FROM JOANNE GORDON

Missouri State
UNIVERSITY

January 22, 2010

Susan Gosnell, MS, RT
Program Director, Radiologic Sciences
University of Central Florida

Dear Ms Gosnell:

This letter grants you permission to use and adapt my survey entitled "Critical Thinking Survey" for your dissertation study exploring the teaching and assessment of critical thinking in Radiologic Technology educational programs. The survey was originally published in my PhD dissertation entitled *Nurse Educators' Perception of Critical Thinking* (1995, University of Missouri-Columbia).

I hope your research goes well and that the survey and information in my dissertation were helpful as you progressed through your research studies. I would be interested in reading your final abstract describing your findings.

Sincerely yours,

Joanne M Gordon

Joanne M Gordon, PhD, RN
Professor Emeritus, Biomedical Sciences
Missouri State University

Current Address:
5047 Stags Leap Lane
Moon Township PA 15108

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APPENDIX B
STAGE ONE SURVEY INSTRUMENT (PILOT)

1. Pilot Study instructions and demographics

Please complete the survey items as they pertain to your own profession and experiences. (The items are currently worded to pertain to radiologic sciences, however, if you are a representative of another health profession, you should answer them as though they are specific to your own field.)

There will be a comment box at the bottom of each page. Please use these to provide specific feedback on the questionnaire items.

Please comment on any aspect of the survey you think will be helpful toward my revisions.

If you prefer to provide feedback to me directly, please email me with your contact information at sgosnell@mail.ucf.edu and I will contact you to set up a convenient time to discuss your findings.

1. Please identify the health profession you represent.

- Athletic Training
- Cardiopulmonary Sciences (Respiratory Therapy)
- Communication Sciences & Disorders
- Nursing
- Physical Therapy
- Radiologic Sciences

Other (please specify)

2. Critical Thinking in Radiologic Science

This list of items is designed to identify your perception of the definition of critical thinking as it applies to radiologic technology.

2. Please specify the degree to which you agree or disagree with the following statements.

	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
1. Critical thinking is a vital skill for radiographers	○	○	○	○	○
2. Critical thinking must be included in radiologic sciences educational programs	○	○	○	○	○
3. Radiologic sciences programs generally do a good job teaching critical thinking	○	○	○	○	○
4. Critical thinking is a generalizable skill	○	○	○	○	○
5. A critical thinker in radiography may not be a critical thinker in other areas or activities	○	○	○	○	○
6. Clinical reasoning and critical thinking are synonymous	○	○	○	○	○
7. Critical thinking is an abstract cognitive activity	○	○	○	○	○
8. Critical thinking is a linear process	○	○	○	○	○
9. Crtical thinking and following protocol are synonymous	○	○	○	○	○
10. Critical thinking is best acquired in liberal arts, non health professions courses	○	○	○	○	○
11. Critical thinking in radiography may be conceptually different than critical thinking in other disciplines	○	○	○	○	○
12. Critical thinking is a rational process	○	○	○	○	○
13. Critical thinking is a series of decisions made by the radiographer in the clinical setting	○	○	○	○	○
14. Critical thinking can be learned	○	○	○	○	○
15. A standard model or definition for critical thinking is needed in radiologic sciences	○	○	○	○	○
16. Critical thinking is a decision making process	○	○	○	○	○
17. Problem-solving and critical thinking are synonymous	○	○	○	○	○
18. Graduates of your program have well-developed critical thinking skills when entering their first radiography job	○	○	○	○	○

Other (please specify)

3. Do you feel the courses in your curriculum provide an opportunity for students to increase their critical thinking skills?

- ◯ Yes
- ◯ No
- ◯ Unsure

4. How is critical thinking incorporated into your curriculum?

- ◯ Specific course in Critical Thinking
- ◯ Integrated in lecture classes only
- ◯ Integrated in clinical courses only
- ◯ Integrated in lab assignments only
- ◯ Integrated in a combination of lecture, lab and clinical courses
- ◯ Not specifically addressed

Other (please specify)

5. To what extent are each of these teaching methods and learning activities utilized in your program in order to enhance the development of critical thinking in your students?

	Consistently	Some of the time	Unsure	Not often used	Not ever used
Case based learning	○	○	○	○	○
Clinical case studies	○	○	○	○	○
Collaborative learning	○	○	○	○	○
Concept mapping	○	○	○	○	○
Didactic lectures	○	○	○	○	○
In class discussions	○	○	○	○	○
Multiple choice test items	○	○	○	○	○
On-line discussions	○	○	○	○	○
Problem based learning	○	○	○	○	○
Reflective journaling	○	○	○	○	○
Role playing	○	○	○	○	○
Socratic questioning	○	○	○	○	○

Other (please specify)

6. Do you include critical thinking as one of your program outcomes reported to JRCERT?

○ Yes

○ No

○ Unsure

7. What measures do you report to document the critical thinking outcome?

8. Please comment on the above items. Do you find any of the items unclear or confusing? Are the lists complete? Are there unnecessary items? Do you have any suggestions for improvement?

3. General Critical Thinking Concepts

This list of items is designed to your perception as to whether the following items are the same thing as critical thinking, part of what critical thinking involves; or completely distinct from critical thinking.

9. Please specify the degree to which you agree that the following items are the same as critical thinking, partly critical thinking; or are not critical thinking.

	Same as critical thinking	Partly critical thinking	Is not critical thinking
1. Empathizing	○	○	○
2. Reasoning deductively	○	○	○
3. Problem-solving	○	○	○
4. Following protocols	○	○	○
5. Planning	○	○	○
6. Sensing (seeing, touching)	○	○	○
7. Speaking or writing	○	○	○
8. Using clinical judgment	○	○	○
9. Defending an opinion	○	○	○
10. Applying reflective skepticism	○	○	○
11. Interrogating, cross-examining	○	○	○
12. Thinking creatively	○	○	○
13. Motivating	○	○	○
14. Managing others	○	○	○
15. Using higher cognitive thinking	○	○	○
16. Judging	○	○	○
17. Reading	○	○	○
18. Communicating through language	○	○	○
19. Decision-making	○	○	○
20. Assessing	○	○	○
21. Utilizing inference	○	○	○
22. Reasoning inductively	○	○	○
23. Exercising reflective judgment	○	○	○
24. Using intuition	○	○	○
25. Implementing a plan	○	○	○
26. Conducting research in a discipline	○	○	○
27. Thinking about thinking	○	○	○
28. Performing routine procedures	○	○	○

Other (please specify)

10. Please comment on the above list. Do you find any of the items unclear or confusing? Is the list complete? Are there unnecessary items? Do you have any suggestions for improvement?

4. Critical Thinking Characteristics

This list of items is designed to identify your perception of specific attributes that you agree are characteristics of a critical thinker.

11. Please specify the degree to which you agree or disagree that the following attributes are characteristics of a critical thinker.

	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
1. Alert to opportunities to use critical thinking	○	○	○	○	○
2. Sensitive to the feelings of others	○	○	○	○	○
3. Creative	○	○	○	○	○
4. Committed	○	○	○	○	○
5. Self-confident in one's own ability to reason	○	○	○	○	○
6. Has a growing sense of responsibility for patient outcomes	○	○	○	○	○
7. Able to recognize patterns in information perceived	○	○	○	○	○
8. Works with complexity in an orderly manner	○	○	○	○	○
9. Open-minded regarding divergent world views	○	○	○	○	○
10. Perceptive of directives for action	○	○	○	○	○
11. Employs deliberative rationality	○	○	○	○	○
12. Prudent in suspending, making or altering judgments	○	○	○	○	○
13. Self-directed	○	○	○	○	○
14. Reasonably selects and applies criteria	○	○	○	○	○
15. Flexible in considering alternatives and opinions	○	○	○	○	○
16. Persistent when difficulties are encountered	○	○	○	○	○
17. Reconsiders and revises views where honest reflection	○	○	○	○	○
18. Suggests that change is warranted	○	○	○	○	○
19. Employs common sense understanding	○	○	○	○	○
20. Demonstrates leadership	○	○	○	○	○
21. Honest in facing personal biases and stereotypes	○	○	○	○	○
22. Precise to the degree permitted by subject and circumstances	○	○	○	○	○
23. Clearly states the question or concern	○	○	○	○	○
24. Fair-minded in appraising reasoning	○	○	○	○	○
25. Inquisitive with respect to a wide range of issues	○	○	○	○	○
26. Focuses attention on the concern at hand	○	○	○	○	○
27. Respects the opinions of others	○	○	○	○	○
28. Assumes responsibility	○	○	○	○	○
29. Trusts in the process of reasoned inquiry	○	○	○	○	○
30. Diligently seeks relevant information	○	○	○	○	○
31. Trustworthy	○	○	○	○	○
32. Recognizes similarities	○	○	○	○	○

33. Concerned about becoming and remaining generally well-informed

Other (please specify)

12. Please comment on the above list. Do you find any of the items unclear or confusing? Is the list complete? Are there unnecessary items? Do you have any suggestions for improvement?

5. Critical Thinking Skills and Abilities

This list of items is designed to identify your perception regarding whether the following skills are used in critical thinking.

13. Please specify the degree to which you agree or disagree that the following skills are used in critical thinking.

	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
1. Employs inference to determine one's position on an issue	○	○	○	○	○
2. Activates diagnostic hypotheses that may explain initial cues presented	○	○	○	○	○
3. Employs non-analytic thinking	○	○	○	○	○
4. Projects a range of possible consequences	○	○	○	○	○
5. Describes the evidence used to interpret a situation	○	○	○	○	○
6. Identifies the reasons advanced to support a conclusion	○	○	○	○	○
7. Expresses one's own opinion	○	○	○	○	○
8. Deduces the consequences flowing from data, principles or opinions	○	○	○	○	○
9. Formulates a variety of alternatives	○	○	○	○	○
10. Explores ethical issues impacting on a solution	○	○	○	○	○
11. Explores legal constraints on decision making	○	○	○	○	○
12. Perceives things as being more or less important	○	○	○	○	○
13. Interprets data in a table or graph	○	○	○	○	○
14. Determines problems, plans solutions, initiates the plan and evaluates outcomes	○	○	○	○	○
15. Monitors own cognitive activities	○	○	○	○	○
16. Reasons resulting in a creative outcome	○	○	○	○	○
17. Identifies conceptual relationships between the parts and the whole	○	○	○	○	○
18. Based on self-examination, determines errors in reasoning	○	○	○	○	○
19. Adapts protocols based on analysis of situation	○	○	○	○	○
20. Judges information to be relevant to the situation	○	○	○	○	○
21. Determines whether statements support a point of view	○	○	○	○	○
22. Recognizes premises requiring support	○	○	○	○	○
23. Expresses meaning of a situation	○	○	○	○	○
24. Acts with others to effect change	○	○	○	○	○
25. Reflects on the influence of bias on one's interpretation of a situation	○	○	○	○	○
26. Recognizes the influence of lack of knowledge or emotions on own objectivity or rationality	○	○	○	○	○

27. Reasons to make decisions, diagnose problems, project outcomes	○	○	○	○	○
28. Judges the credibility of a source	○	○	○	○	○
29. Reasons without the use of analytic methods or deliberate calculations	○	○	○	○	○
30. Initiates and completes actions necessary to accomplish defined goals	○	○	○	○	○
31. Uses analogy to remove ambiguity	○	○	○	○	○
32. Produces accurate statements resulting from reasoning activities	○	○	○	○	○
33. Aware of past, present, or future events	○	○	○	○	○
34. Chooses interventions to resolve problems	○	○	○	○	○
35. Recognizes cues	○	○	○	○	○
36. Generates and tests diagnostic hypotheses	○	○	○	○	○
37. Recognizes the relevance of information	○	○	○	○	○
38. Assesses the contextual relevance of information	○	○	○	○	○
39. Justifies one's own reasoning process	○	○	○	○	○

Other (please specify)

14. Please comment on the above list. Do you find any of the items unclear or confusing? Is the list complete? Are there unnecessary items? Do you have any suggestions for improvement?

6. Program and faculty demographics

This demographic information will be used to correlate survey responses to faculty characteristics and type of educational program.

15. Specify the type of organization that sponsors your educational program.

- ◯ Hospital/Medical Center
- ◯ Private College/University
- ◯ Public Community College
- ◯ Public University

Other (please specify)

16. Please idicate the terminal degree awarded to graduates of your program.

- ◯ Associate Degree
- ◯ Certificate/Diploma
- ◯ Baccalaureate Degree

Other (please specify)

17. Please indicate the size of your program according to the annual enrollment of first year students.

- ◯ less than 10
- ◯ 11 - 20
- ◯ 21 - 30
- ◯ 31 - 40
- ◯ greater than 40

18. Please indicate you current position title.

- ◯ Clinical Coordinator
- ◯ Clinical Instructor
- ◯ Didactic Instructor
- ◯ Program Director

Other (please specify)

19. How many years have you been teaching in a Radiologic Sciences program?

- ◯ less than 5 years
- ◯ 5 - 9 years
- ◯ 10 - 14 years
- ◯ 15 - 19 years
- ◯ 20 - 24 years
- ◯ 25 years or more

20. Please indicate your highest level of completed educational preparation.

- ◯ Doctoral degree, please specify area in the box below
- ◯ Masters degree, please specify area in the box below
- ◯ Bachelor's degree, please specify area in the box below
- ◯ Associate degree, please specify area in the box below
- ◯ Other, please specify area in the box below

please specify your area of academic study

21. Please comment on the above items. Do you find any of the items unclear or confusing? Is the information requested complete? Are there unnecessary items? Do you have any suggestions for improvement?

7. Final insights and feedback

Please answer the following general follow up questions.

22. How long did it take you to complete the survey items on this questionnaire?

- ◯ 5 - 10 minutes
- ◯ 10 - 15 minutes
- ◯ 15 - 20 minutes
- ◯ 20 - 25 minutes
- ◯ 25 - 30 minutes

Other (please specify)

23. Please comment on the length of the survey and general ease in completing it.

24. Please comment on the appropriateness and clarity of the specific items.

25. Please provide any other insights you feel would help me to improve this survey.

APPENDIX C
GORDON'S RATIONALE FOR SURVEY ITEM INCLUSION

Table1: General critical thinking Concepts - Part Two

Facione	Higher order thinking	Nursing process	Other thinking skills
Empathizing	Thinking creatively	Assessing	Applying reflective skepticism
Problem-solving	Thinking about thinking	Implementing a plan	Exercising reflective judgment
Planning	Using higher cognitive thinking	Using clinical judgment	Judging
Sensing-seeing, touching		Using intuition	Reasoning deductively
Speaking or writing			Reasoning inductively
Defending an opinion			Utilizing inference
Interrogating, cross-examining			Performing routine procedures
Motivating			Following protocols
Managing others			
Reading			
Communicating through language			
Decision-making			
Conducting research in a discipline			

Table 2:Critical thinking dispositions - Part Three

Facione	Professional characteristics	Nursing process	Clinical judgment	Miscellaneous
Alert to opportunities to use critical thinking Self-confident in one's own ability to reason Works with complexity in an orderly manner Open-minded regarding divergent world views Prudent in suspending, making or altering judgments Reasonably selects and applies criteria Flexible in considering alternatives and opinions Persistent when difficulties are encountered Reconsiders and revises views where honest reflection suggests that change is warranted Honest in facing personal biases and stereotypes Precise to the degree permitted by subject and circumstances Clearly states the question or concern Fair-minded in appraising reasoning Inquisitive with respect to a wide range of issues Focuses attention on the concern at hand Respects the opinions of others Trusts in the process of reasoned inquiry Diligently seeks relevant information Concerned about becoming and remaining generally well-informed	Assumes responsibility Self-directed	Creative Committed Demonstrates leadership Trustworthy	Able to recognize patterns in information perceived Employs common sense understanding Employs deliberative rationality Has a growing sense of responsibility for patient outcomes Perceptive of directives for action Recognizes similarities	Sensitive to the feelings of others

Table 3: Critical thinking skills and abilities - Part Four

Facione
Interpretation
Interprets data in a table or graph Expresses meaning of a situation Uses analogy to remove ambiguity
Analysis
Determines whether statements support a point of view Identifies the reasons advanced to support a conclusion Justifies one's own reasoning process Adapts protocols based on analysis of situation
Evaluation
Assesses the contextual relevance of information Identifies conceptual relationships between the parts and the whole Judges the credibility of a source Judges information to be relevant to the situation Recognizes the relevance of information
Inference
Deduces the consequences flowing from data, principles or opinions Employs inference to determine one's position on an issue presented Formulates a variety of alternatives Projects a range of possible consequences Recognizes premises requiring support
Explanation
Describes the evidence used to interpret a situation Produces accurate statements resulting from reasoning activities
Self-regulation
Based on self-examination, determines errors in reasoning Recognizes the influence of lack of knowledge or emotions on own objectivity or rationality Monitors own cognitive activities Reflects on the influence of bias on one's interpretation of a situation

Clinical reasoning	Nursing process	Intuition	Creativity	Ethical decision making	Miscellaneous
Activates diagnostic hypotheses that may explain initial cues Chooses interventions to resolve problems Generates and tests diagnostic hypotheses Reasons to make decisions, diagnose problems, project outcomes Recognizes cues	Initiates and completes actions necessary to accomplish defined goals Determines problems, plans solutions, initiates the plan and evaluates outcomes	Aware of past, present, or future events Reasons without the use of analytic methods or deliberate calculations Perceives things as being more or less important Employs non-analytic thinking	Reasons resulting in a creative outcome	Explores ethical issues impacting on a solution. Explores legal constraints on decision making.	Acts with others to effect change Expresses one's own opinion

APPENDIX D
STAGE TWO - REVISED SURVEY INSTRUMENT

Critical Thinking in Radiologic Sciences Survey (adapted from

A. Critical Thinking in Radiologic Science

This section is designed to identify your perception of the definition of critical thinking as it applies to radiologic technology.

1. Please specify the degree to which you agree or disagree with the following statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Critical thinking is a vital skill for radiographers	◯	◯	◯	◯	◯
Critical thinking must be included in radiologic sciences educational programs	◯	◯	◯	◯	◯
Radiologic sciences programs generally do a good job teaching critical thinking	◯	◯	◯	◯	◯
Critical thinking is a generalizable skill (can be applied to many different activities)	◯	◯	◯	◯	◯
A critical thinker in radiography may not be a critical thinker in other (non-health care)areas or activities	◯	◯	◯	◯	◯
Clinical reasoning and critical thinking are synonymous	◯	◯	◯	◯	◯
Critical thinking is an abstract cognitive activity	◯	◯	◯	◯	◯
Critical thinking is a linear process	◯	◯	◯	◯	◯
Critical thinking and following protocol are synonymous	◯	◯	◯	◯	◯
Critical thinking is best acquired in liberal arts, non health professions courses	◯	◯	◯	◯	◯
Critical thinking in radiography may be conceptually different than critical thinking in other health care disciplines	◯	◯	◯	◯	◯
Critical thinking is a rational process	◯	◯	◯	◯	◯
Critical thinking is a series of decisions made by the radiographer in the clinical setting	◯	◯	◯	◯	◯
Critical thinking can be learned	◯	◯	◯	◯	◯
A standard model or definition for critical thinking is needed in radiologic sciences	◯	◯	◯	◯	◯
Critical thinking is synonymous with decision making processes	◯	◯	◯	◯	◯
Problem-solving and critical thinking are synonymous	◯	◯	◯	◯	◯
Graduates of your program have well-developed critical thinking skills when entering their first radiography job	◯	◯	◯	◯	◯

**2. How is critical thinking incorporated into your curriculum?
Choose all that apply.**

- ☐ Not specifically addressed
- ☐ Separate course in Critical Thinking
- ☐ Integrated in lecture classes
- ☐ Integrated in clinical courses
- ☐ Integrated in lab assignments
- ☐ Other, Please explain.

**3. Which courses in your curriculum provide an opportunity for students to increase their critical thinking skills?
Choose all that apply.**

- ☐ Introduction to Radiologic Science
- ☐ Patient Care
- ☐ Radiographic Procedures
- ☐ Procedures labs
- ☐ Radiographic Exposures & Technique
- ☐ Exposures labs
- ☐ Radiation Physics
- ☐ Physics labs
- ☐ Radiation Biology & Protection
- ☐ Other, please specify

Critical Thinking in Radiologic Sciences Survey (adapted from

B. Teaching Strategies

This section is desigined to document your perceptions of appropriate teaching strategies and identify the types of strategies currently used in your program.

4. To what extent do you agree or disagree that each of the following teaching methods and learning activities are effective for the development of critical thinking in your students?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Socratic questioning	○	○	○	○	○
On-line discussions	○	○	○	○	○
In class discussions	○	○	○	○	○
Traditional lectures	○	○	○	○	○
Clinical case studies	○	○	○	○	○
Reflective journaling	○	○	○	○	○
Concept mapping	○	○	○	○	○
High order multiple choice test items	○	○	○	○	○
Situational judgment test items	○	○	○	○	○
Role playing	○	○	○	○	○
Case based learning	○	○	○	○	○
Problem based learning	○	○	○	○	○
Collaborative learning	○	○	○	○	○
Portfolios	○	○	○	○	○
Other methods used (please specify)	○	○	○	○	○

Other methods used (please specify)

Critical Thinking in Radiologic Sciences Survey (adapted from

5. What percentage of your curriculum utilizes each of these teaching methods and learning activities?

	never used	less than 10%	10 - 24%	25 - 49%	50 - 74%	75 - 100%	Unsure
Socratic questioning	◯	◯	◯	◯	◯	◯	◯
On-line discussions	◯	◯	◯	◯	◯	◯	◯
In class discussions	◯	◯	◯	◯	◯	◯	◯
Traditional lectures	◯	◯	◯	◯	◯	◯	◯
Clinical case studies	◯	◯	◯	◯	◯	◯	◯
Reflective journaling	◯	◯	◯	◯	◯	◯	◯
Concept mapping	◯	◯	◯	◯	◯	◯	◯
High order multiple choice test items	◯	◯	◯	◯	◯	◯	◯
Situational judgment test items	◯	◯	◯	◯	◯	◯	◯
Role playing	◯	◯	◯	◯	◯	◯	◯
Case based learning	◯	◯	◯	◯	◯	◯	◯
Problem based learning	◯	◯	◯	◯	◯	◯	◯
Collaborative learning	◯	◯	◯	◯	◯	◯	◯
Portfolios	◯	◯	◯	◯	◯	◯	◯
Other methods (please specify)	◯	◯	◯	◯	◯	◯	◯

Other methods (please specify)

Critical Thinking in Radiologic Sciences Survey (adapted from

C. Assessment Measures

This section is designed to document your perceptions of appropriate assessment measures and identify the types of measures currently in use to document learning outcomes for the JRCERT.

6. To what extent do you agree or disagree that each of the following are appropriate assessment measures of critical thinking in your students?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Course exam results	○	○	○	○	○
ARRT exam results	○	○	○	○	○
Clinical competency results	○	○	○	○	○
Image critique performance	○	○	○	○	○
Specific course assignments	○	○	○	○	○
Situational judgment test items	○	○	○	○	○
Portfolios	○	○	○	○	○
Reflective Journals	○	○	○	○	○
Clinical case study performance	○	○	○	○	○
Employer surveys	○	○	○	○	○
Student surveys	○	○	○	○	○
Standardized test results (such as the WGCTA or CCTST)	○	○	○	○	○
Other assessment measures used (please specify)	○	○	○	○	○

Other assessment measures used (please specify)

7. Which assessment measures do you report to the JRCERT as tools used to document critical thinking as a programatic learning outcome? (Choose all that apply)

- [ ] Course exam results
- [ ] ARRT exam results
- [ ] Clincal competency results
- [ ] Image critique performance
- [ ] Specific course assignments
- [ ] Situational judgment test items
- [ ] Portfolios
- [ ] Reflective Journals
- [ ] Clinical case study performance
- [ ] Employer surveys
- [ ] Student surveys
- [ ] Standardized test (such as the WGCTA or CCTST)
- [ ] Other assessment measures used (please specify)

D. Critical Thinking Attributes

This section is designed to identify your perception of specific attributes that are considered to be the same as critical thinking.

8. Please specify the degree to which agree or disagree that the following attributes are considered the same as critical thinking.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Empathizing	○	○	○	○	○
Deductive reasoning	○	○	○	○	○
Inductive reasoning	○	○	○	○	○
Problem-solving	○	○	○	○	○
Following protocols	○	○	○	○	○
Planning	○	○	○	○	○
Sensing (seeing, touching, hearing)	○	○	○	○	○
Speaking or writing	○	○	○	○	○
Using clinical judgment	○	○	○	○	○
Defending an opinion	○	○	○	○	○
Applying reflective skepticism	○	○	○	○	○
Judging evidence to be more or less important	○	○	○	○	○
Interrogating, cross-examining	○	○	○	○	○
Thinking creatively	○	○	○	○	○
Motivating others	○	○	○	○	○
Managing others	○	○	○	○	○
Using higher cognitive thinking	○	○	○	○	○
Reading	○	○	○	○	○
Communicating verbally	○	○	○	○	○
Exploring ethical issues impacting a solution	○	○	○	○	○
Interpreting data on a table or graph	○	○	○	○	○
Exercising reflective reasoning	○	○	○	○	○
Reasoning intuitively	○	○	○	○	○
Performing routine procedures	○	○	○	○	○
Conducting research in a discipline	○	○	○	○	○
Implementing a plan	○	○	○	○	○
Thinking about thinking	○	○	○	○	○
Recognizing cues	○	○	○	○	○
Judging the credibility of a source	○	○	○	○	○

Critical Thinking in Radiologic Sciences Survey (adapted from

Adapting protocols based on analysis of a situation	◯	◯	◯	◯	◯
Reasoning to make decisions, diagnose problems, project outcomes	◯	◯	◯	◯	◯
Growing sense of responsibility for patient outcomes	◯	◯	◯	◯	◯

Critical Thinking in Radiologic Sciences Survey (adapted from

E. Program and faculty demographics

This demographic information will be used to correlate survey responses to faculty characteristics and type of educational program.

9. Specify the type of organization that sponsors your educational program.

- Hospital/Medical Center
- Public Community College
- Private College/University
- Public College/University
- Other (please specify)

10. Please indicate the terminal degree awarded to graduates of your program.

- Certificate/Diploma
- Associate Degree
- Baccalaureate Degree
- Other (please specify)

11. Please indicate the size of your program according to the annual enrollment of first year students.

- less than 10
- 10 - 20
- 21 - 30
- 31 - 40
- greater than 40

12. How did you develop you personal perception of critical thinking? Select all that apply.

- [ ] Formal coursework in graduate school
- [ ] Informally through discussions with health professions faculty
- [ ] Informally through discussions with non-health professions faculty
- [ ] By attending conferences, workshops or seminars in critical thinking
- [ ] By reading professional journals
- [ ] Other, please specify

13. Please indicate your highest level of completed educational preparation.

- ○ Doctoral degree, please specify area in the box below
- ○ Masters degree, please specify area in the box below
- ○ Bachelor's degree, please specify area in the box below
- ○ Associate degree, please specify area in the box below
- ○ Other, please specify area in the box below

please specify your area of academic study

14. Which professional credentials do you currently hold? Select all that apply.

- ☐ Computed Tomography (CT)
- ☐ Bone Densitometry (BD)
- ☐ Cardiac-interventional radiography (CI)
- ☐ Nuclear Medicine (N)
- ☐ Magnetic Resonance (MR)
- ☐ Cardiovascular-interventional radiography (CV)
- ☐ Mammography (M)
- ☐ Sonography (S)
- ☐ Radiography (R)
- ☐ Vascular-interventional radiography (VI)
- ☐ Quality Management (QM)
- ☐ Radiation Therapy (T)

15. How many years have you been teaching in a Radiologic Sciences program?

- ○ less than 5 years
- ○ 5 - 9 years
- ○ 10 - 14 years
- ○ 15 - 19 years
- ○ 20 - 24 years
- ○ 25 years or more

16. How many years did you practice as a radiographer before becoming an educator in a Radiologic Sciences program?

- ◯ am still practicing as a radiographer in addition to teaching
- ◯ less than 5 years
- ◯ 5 - 9 years
- ◯ 10 - 14 years
- ◯ 15 - 19 years
- ◯ 20 - 24 years
- ◯ 25 years or more

APPENDIX E
CORRESPONDENCE TO SURVEY PARTICIPANTS

Preliminary notice------Via Email-------

April 2, 2010

Dear Colleague,

I am the director of the Radiologic Sciences program and a doctoral student at the University of Central Florida (UCF) in Orlando. A few days from now, you will receive an email request for you to complete a short survey regarding critical thinking in the Radiologic Sciences. It is important that all the Radiologic Technology program directors contacted will participate so that the results are meaningful.

I am contacting you now to give you advanced notice of the coming survey because I know you are busy and have found that people often appreciate knowing ahead of time that they will be contacted. This study is important because the results will help establish a foundation of understanding about how we as Radiologic Science educators define, teach and assess critical thinking in our programs.

Critical thinking is a major educational outcome required for recognition by the JRCERT. It is important therefore that we come to a consensus regarding how we define critical thinking within the practice of diagnostic imaging and establish the groundwork from which to identify appropriate teaching strategies and assessment methods.

Thank you in advance for your willingness to participate in this survey. I look forward to reading your insights into this important topic.

Sincerely,

Susan D. Gosnell M.S., R.T.(R)(CT)(QM)(MR)
Doctoral Candidate and Radiologic Sciences Program Director
sgosnell@mail.ucf.edu
407-823-3415

If you wish to opt out of receiving any further communication from me concerning this study simply reply to this email and I will remove your contact information from my database.

Cover letter ------ via email------

April, 2010

Dear Colleague,

I am the director of the Radiologic Sciences program and a doctoral student at the University of Central Florida (UCF) in Orlando. I need your help to complete my research. Please complete this survey concerning critical thinking in Radiologic Technology, including its definition, appropriate teaching strategies and assessment methods.

Critical thinking is a major educational outcome required for accreditation and recognition by the JRCERT. It is important therefore that we come to a consensus regarding how we define critical thinking within the practice of diagnostic imaging and establish the groundwork from which to identify appropriate teaching strategies and assessment methods.

This is a nationwide survey including all JRCERT accredited programs within the United States.

This survey should only take 15 minutes of your time. Your responses will be completely anonymous since I will only receive data from Survey Monkey® after all identifying information has been removed. Your consent to participate in this research will be confirmed by clicking on the survey link below. Your participation is voluntary. You may choose to discontinue your participation at any time during the survey and may skip any items you are not comfortable answering. You must be 18 years of age or older to take part in this research study.

To consent to participating in this research study and to complete the survey,
click here Critical Thinking Survey

If you have any questions concerns, or complaints about this research study, please feel free to contact me, Susan Gosnell, Doctoral candidate, Curriculum & Instruction program, at (407) 823-3415 or by email at sgosnell@mail.ucf.edu . Or contact my faculty supervisor, Dr. Karen Biraimah, College of Education at (407) 823-2428, or by email at biraimah@mailucf.edu .

All research at the University of Central Florida is conducted under the supervision of the UCF Institutional Review Board (IRB). Questions or concerns about research participants' rights may be directed to the UCF IRB office, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246. The IRB phone number is (407) 823-2901.

Sincerely,

Susan D. Gosnell M.S., R.T., (R)(CT)(QM)(MR)
Doctoral Candidate and Radiologic Sciences Program Director

Reminder letter------ Via email ------

April, 2010

About two weeks ago, you received an email requesting your participation in a questionnaire regarding critical thinking in the Radiologic Sciences. The database through Survey Monkey® reveals that you have not yet had the opportunity to complete this survey.

I really need your help and would greatly appreciate your sharing your expertise and insights by completing my survey.

I believe it is so important to advance the professionalization of the Radiologic Sciences. We can do this by establishing our own research base in areas such as critical thinking as it applies to diagnostic imaging. This survey covers how we as educators perceive the definition of critical thinking as well as appropriate teaching strategies and assessment methods currently in use.

This survey should only take about 15 minutes of your time. Your identity will remain completely anonymous and your responses will be released only as summary data. This questionnaire is voluntary. However, you can help me immensely by taking a few minutes to share your insights.

In case you no longer have the original email, I have attached the link to Survey Monkey® again.

To consent to participating in this research study and to complete the survey,
click here Critical Thinking Survey

If you have any questions concerns, or complaints about this research study, please feel free to contact me, Susan Gosnell, Doctoral candidate, Curriculum & Instruction program, at (407) 823-3415 or by email at sgosnell@mail.ucf.edu . Or contact my faculty supervisor, Dr. Karen Biraimah, College of Education at (407) 823-2428, or by email at biraimah@mailucf.edu .

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Sincerely,

Susan D. Gosnell M.S., R.T., (R)(CT)(QM)(MR)
Doctoral Candidate and Radiologic Sciences Program Director

Final reminder letter------ Via email ------

April, 2010

I am currently trying to wrap up the data collection portion of my dissertation research regarding critical thinking in the Radiologic Sciences. If you have not yet completed this survey I would really appreciate if you take the time now to submit it. I still need a large number of additional responses.

I believe it is so important to advance the professionalization of the Radiologic Sciences. We can do this by establishing our own research base in areas such as critical thinking as it applies to diagnostic imaging. This survey covers how we as educators perceive the definition of critical thinking as well as appropriate teaching strategies and assessment methods currently in use.

I am sure that you are as busy as I am, so I definitely understand how hard it can be to find time for this kind of request. However, I would so appreciate your participation since it is only by sharing your expertise and insights that I can truly understand where we stand as a profession regarding this important learning outcome.

This survey should only take about 10 - 15 minutes of your time. Because I am on a pretty tight schedule, I will be closing the survey on Monday, May 3.

In case you no longer have the original email, I have attached the link to Survey Monkey® again. If you think that you have already completed it, it is possible that Survey Monkey did not recognize your submission as completed and is still holding it open. If you click on the link, it will take you back into your survey and you can resubmit it without needing to fill in the answers again.

To consent to participating in this research study and to complete the survey;
Click here http://www.surveymonkey.com/s/HZJR2SM

If you have any questions, concerns or complaints about this research study, please feel free to contact me, Susan Gosnell, Doctoral candidate, Curriculum & Instruction program, at (407) 823-3415 or by email at sgosnell@mail.ucf.edu . Or contact my faculty supervisor, Dr. Karen Biraimah, College of Education at (407) 823-2428, or by email at biraimah@mailucf.edu .

All research at the University of Central Florida is conducted under the supervision of the UCF Institutional Review Board (IRB). Questions or concerns about research participants' rights may be directed to the UCF IRB office, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246. The IRB phone number is (407) 823-2901.

Sincerely,

Susan D. Gosnell M.S., R.T., (R) (CT) (QM) (MR)
Doctoral Candidate and Radiologic Sciences Program Director

Thank you ------via email------

April, 2010

Dear Colleague,

Thank you for your participation in my research study. Your insights into this important concept are invaluable to me. Results from this questionnaire will help establish a foundation of understanding about how we as Radiologic Science educators define, teach and assess critical thinking in our programs. This is turn will allow renewed conversation among programs regarding this important learning outcome and advance our efforts to establish Radiologic Sciences as a true profession.

If you have any questions or insights about this research study, please feel free to contact me at (407) 823-3415 or by email at sgosnell@mail.ucf.edu . My faculty supervisor is Dr. Karen Biraimah (407) 823-2428.

All research at the University of Central Florida is conducted under the supervision of the UCF Institutional Review Board (IRB). Questions or concerns about research participants' rights may be directed to the UCF IRB office, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246. The IRB phone number is (407) 823-2901.

Sincerely,

Susan D. Gosnell M.S., R. T., (R)(CT)(QM)(MR)
Doctoral Candidate and Radiologic Sciences Program Director

APPENDIX F
IRB APPROVAL/EXEMPTION NOTIFICATION

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2012 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

NOT HUMAN RESEARCH DETERMINATION

From : **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To : **Susan D. Gosnell**

Date : **November 12, 2009**

Dear Researcher:

On 11/12/2009, the IRB determined that the following proposed activity is not human research as defined by DHHS regulations at 45 CFR 46 or FDA regulations at 21 CFR 50/56:

Type of Review:	Not Human Research Determination
Project Title:	Pilot Test of Critical Thinking in Radiologic Technology Questionnaire
Investigator:	Susan D. Gosnell
IRB ID:	SBE-09-06530
Funding Agency:	
Grant Title:	
Research ID:	n/a

University of Central Florida IRB review and approval is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are to be made and there are questions about whether these activities are research involving human subjects, please contact the IRB office to discuss the proposed changes.

On behalf of the IRB Chair, Joseph Bielitzki, DVM, this letter is signed by:

Signature applied by Joanne Muratori on 11/12/2009 09:55:11 AM EST

Joanne Muratori

IRB Coordinator

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Susan D. Gosnell**

Date: **April 01, 2010**

Dear Researcher:

On 4/1/2010, the IRB approved the following activity as human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Project Title:	Teaching and Assessing Critical Thinking in Radiologic Technology Students
Investigator:	Susan D Gosnell
IRB Number:	SBE-10-06869
Funding Agency:	
Grant Title:	
Research ID:	NA

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Joseph Bielitzki, DVM, UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 04/01/2010 10:21:19 AM EST

Joanne Muratori

IRB Coordinator

Page 1 of 1

APPENDIX G
SUMMARY DESCRIPTIVE DATA

Table 1: Descriptive Summary (by program level) Critical Thinking in Radiologic Sciences – Part A

Variables	Certificate/diploma				Associate degree				Bachelors degree				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Critical thinking is a vital skill for radiographers	84	4.82	5.00	.415	154	4.85	5.00	.375	34	4.76	5.00	.431	272	4.83	5.00	.395
Critical thinking must be included in radiologic sciences educational programs	84	4.58	5.00	.732	154	4.73	5.00	.472	34	4.74	5.00	.448	272	4.69	5.00	.565
Radiologic sciences programs generally do a good job teaching critical thinking	82	3.68	4.00	.859	153	3.69	4.00	.845	34	3.62	4.00	.853	269	3.68	4.00	.848
Critical thinking is a generalizable skill (can be applied to many different activities)	84	4.37	4.00	.655	154	4.27	4.00	.750	33	4.27	4.00	.876	271	4.30	4.00	.737
A critical thinker in radiography may not be a critical thinker in other (non-health care)areas or activities	82	3.26	3.00	1.004	153	3.08	3.00	1.026	34	2.62	2.50	1.101	269	3.08	3.00	1.043
Clinical reasoning and critical thinking are synonymous	84	3.29	3.50	.926	154	3.41	4.00	.994	33	3.33	4.00	1.051	271	3.36	4.00	.979
Critical thinking is an abstract cognitive activity	81	3.33	4.00	.962	150	3.35	4.00	1.031	34	3.09	4.00	1.138	265	3.31	4.00	1.024

(Program level spans Certificate/diploma, Associate degree, Bachelors degree.)

Variables	Program level															
	Certificate/diploma				Associate degree				Bachelors degree				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Critical thinking is a linear process	83	2.83	3.00	.948	154	2.81	3.00	1.042	34	2.50	2.00	.929	271	2.77	3.00	1.002
Critical thinking and following protocol are synonymous	84	1.94	2.00	.750	153	2.16	2.00	.911	34	1.82	2.00	.968	271	2.05	2.00	.879
Critical thinking is best acquired in liberal arts, non health professions courses	83	1.90	2.00	.655	154	1.78	2.00	.734	34	1.59	2.00	.657	271	1.79	2.00	.706
Critical thinking in radiography may be conceptually different than critical thinking in other health care disciplines	83	3.24	3.00	.970	153	3.09	3.00	1.078	33	3.00	3.00	1.250	269	3.13	3.00	1.068
Critical thinking is a rational process	81	3.78	4.00	.791	152	3.95	4.00	.740	34	3.82	4.00	.834	267	3.88	4.00	.769
Critical thinking is a series of decisions made by the radiographer in the clinical setting	84	4.05	4.00	.675	154	3.94	4.00	.822	34	3.74	4.00	.931	272	3.94	4.00	.797
Critical thinking can be learned	84	4.07	4.00	.597	153	4.01	4.00	.678	34	3.91	4.00	.621	271	4.02	4.00	.647
A standard model or definition for critical thinking is needed in radiologic sciences	84	3.81	4.00	.938	153	3.81	4.00	.901	34	3.68	4.00	1.007	271	3.79	4.00	.924

Variables	Program level												Total			
	Certificate/diploma				Associate degree				Bachelors degree							
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Critical thinking is synonymous with decision making processes	83	3.71	4.00	.969	154	3.66	4.00	.917	33	3.36	4.00	.994	270	3.64	4.00	.945
Problem-solving and critical thinking are synonymous	84	3.90	4.00	.845	151	3.79	4.00	.914	34	3.68	4.00	.945	269	3.81	4.00	.896
Graduates of your program have well-developed critical thinking skills when entering their first radiography job	84	3.93	4.00	.690	154	3.84	4.00	.648	34	3.85	4.00	.558	272	3.87	4.00	.650

Table 2: Descriptive Summary (by highest degree) Critical Thinking in Radiologic Sciences – Part A

Variables	Program director – highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Critical thinking is a vital skill for radiographers	30	4.87	5.00	.346	233	4.82	5.00	.404	8	4.88	5.00	.354	271	4.83	5.00	.395
Critical thinking must be included in radiologic sciences educational programs	30	4.73	5.00	.450	233	4.68	5.00	.583	8	4.75	5.00	.463	271	4.69	5.00	.565
Radiologic sciences programs generally do a good job teaching critical thinking	30	3.67	4.00	.884	230	3.69	4.00	.855	8	3.38	3.00	.518	268	3.68	4.00	.850
Critical thinking is a generalizable skill (can be applied to many different activities)	30	4.47	5.00	.681	232	4.28	4.00	.751	8	4.50	4.50	.535	270	4.30	4.00	.739
A critical thinker in radiography may not be a critical thinker in other (non-health care)areas or activities	30	2.83	3.00	1.206	230	3.11	3.00	1.030	8	3.13	3.50	.991	268	3.08	3.00	1.050
Clinical reasoning and critical thinking are synonymous	30	3.13	3.00	1.042	232	3.39	4.00	.983	8	3.13	3.00	.835	270	3.36	4.00	.987

Variables	Program director – highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Critical thinking is an abstract cognitive activity	29	3.00	3.00	1.035	227	3.35	4.00	1.029	8	3.50	3.50	.926	264	3.31	4.00	1.030
Critical thinking is a linear process	30	2.70	2.50	.952	232	2.80	3.00	1.027	8	2.75	2.50	.886	270	2.79	3.00	1.012
Critical thinking and following protocol are synonymous	30	1.97	2.00	.850	232	2.07	2.00	.906	8	2.00	2.00	.926	270	2.06	2.00	.898
Critical thinking is best acquired in liberal arts, non health professions courses	30	1.77	2.00	.858	232	1.80	2.00	.723	8	2.00	2.00	.535	270	1.80	2.00	.733
Critical thinking in radiography may be conceptually different than critical thinking in other health care disciplines	30	3.03	3.00	1.217	230	3.16	3.00	1.059	8	2.50	2.00	.926	268	3.13	3.00	1.077
Critical thinking is a rational process	30	3.87	4.00	.776	229	3.90	4.00	.782	7	4.00	4.00	.000	266	3.89	4.00	.770
Critical thinking is a series of decisions made by the radiographer in the clinical setting	30	4.00	4.00	.743	233	3.96	4.00	.798	8	3.75	4.00	.886	271	3.96	4.00	.792
Critical thinking can be learned	30	4.10	4.00	.712	232	4.01	4.00	.655	8	4.00	4.00	.000	270	4.02	4.00	.651

Variables	Program director – highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
A standard model or definition for critical thinking is needed in radiologic sciences	30	3.70	4.00	1.022	233	3.80	4.00	.921	7	4.29	4.00	.488	270	3.80	4.00	.926
Critical thinking is synonymous with decision making processes	30	3.47	4.00	1.074	231	3.67	4.00	.930	8	3.63	4.00	1.061	269	3.65	4.00	.949
Problem-solving and critical thinking are synonymous	30	3.57	4.00	.817	230	3.85	4.00	.915	8	3.75	4.00	.707	268	3.81	4.00	.901
Graduates of your program have well-developed critical thinking skills when entering their first radiography job	30	3.87	4.00	.507	233	3.89	4.00	.667	8	3.38	3.00	.518	271	3.87	4.00	.651

Table 3: Descriptive Summary (by program level) Critical Thinking attributes – Part D

Variables	Certificate/diploma N	Certificate/diploma Mean	Certificate/diploma Median	Certificate/diploma Std. Deviation	Associate degree N	Associate degree Mean	Associate degree Median	Associate degree Std. Deviation	Bachelors degree N	Bachelors degree Mean	Bachelors degree Median	Bachelors degree Std. Deviation	Total N	Total Mean	Total Median	Total Std. Deviation
Empathizing	83	3.01	3.00	1.018	151	2.77	3.00	1.048	34	2.59	3.00	.957	268	2.82	3.00	1.034
Deductive reasoning	84	4.19	4.00	.526	152	4.21	4.00	.637	34	4.12	4.00	.478	270	4.19	4.00	.585
Inductive reasoning	84	4.00	4.00	.621	151	4.06	4.00	.645	33	4.18	4.00	.528	268	4.06	4.00	.625
Problem-solving	84	4.37	4.00	.576	151	4.42	4.00	.547	34	4.29	4.00	.629	269	4.39	4.00	.567
Following protocols	84	2.93	3.00	.902	148	2.72	3.00	1.049	34	2.44	2.00	.894	266	2.75	3.00	.994
Planning	84	3.86	4.00	.747	149	3.65	4.00	.915	33	3.70	4.00	.883	266	3.72	4.00	.863
Sensing (seeing, touching, hearing)	84	3.45	4.00	.870	149	3.43	4.00	1.041	34	3.21	3.00	.914	267	3.41	4.00	.974
Speaking or writing	84	3.52	4.00	.857	148	3.39	3.00	.966	33	3.36	3.00	.859	265	3.43	4.00	.919
Using clinical judgment	84	4.45	4.00	.501	152	4.40	4.00	.643	34	4.26	4.00	.511	270	4.40	4.00	.587
Defending an opinion	83	3.88	4.00	.903	150	3.91	4.00	.768	34	3.94	4.00	.814	267	3.91	4.00	.815
Applying reflective skepticism	83	3.84	4.00	.707	150	3.83	4.00	.709	34	3.88	4.00	.686	267	3.84	4.00	.703
Judging evidence to be more or less important	83	4.08	4.00	.609	151	4.00	4.00	.712	34	3.82	4.00	.869	268	4.00	4.00	.706
Interrogating, cross-examining	84	3.61	4.00	.822	151	3.72	4.00	.881	34	3.68	4.00	.843	269	3.68	4.00	.856
Thinking creatively	84	4.19	4.00	.611	152	4.12	4.00	.754	34	4.03	4.00	.674	270	4.13	4.00	.702
Motivating others	84	3.54	4.00	.752	151	3.36	4.00	1.029	34	3.38	3.00	1.045	269	3.42	4.00	.953

Variables	Program level															
	Certificate/diploma				Associate degree				Bachelors degree				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Managing others	83	3.60	4.00	.826	151	3.50	4.00	.930	34	3.44	3.00	1.021	268	3.53	4.00	.909
Using higher cognitive thinking	83	4.29	4.00	.553	151	4.21	4.00	.715	33	4.30	4.00	.585	267	4.24	4.00	.652
Reading	84	3.27	3.00	.883	151	3.20	3.00	.993	34	3.56	3.50	.927	269	3.27	3.00	.956
Communicating verbally	84	3.57	4.00	.997	150	3.53	4.00	.981	34	3.56	4.00	.991	268	3.54	4.00	.984
Exploring ethical issues impacting a solution	82	4.26	4.00	.540	148	4.15	4.00	.722	34	4.21	4.00	.641	264	4.19	4.00	.660
Interpreting data on a table or graph	83	3.65	4.00	.833	151	3.62	4.00	.885	34	3.76	4.00	.699	268	3.65	4.00	.846
Exercising reflective reasoning	84	4.15	4.00	.630	152	4.01	4.00	.723	34	4.00	4.00	.696	270	4.05	4.00	.693
Reasoning intuitively	83	4.01	4.00	.741	150	3.82	4.00	.905	34	3.74	4.00	.963	267	3.87	4.00	.868
Performing routine procedures	83	3.12	3.00	1.005	151	3.05	3.00	1.054	34	2.88	3.00	1.200	268	3.05	3.00	1.057
Conducting research in a discipline	84	3.68	4.00	.853	151	3.61	4.00	.938	33	3.85	4.00	.795	268	3.66	4.00	.895
Implementing a plan	84	3.80	4.00	.803	149	3.72	4.00	.869	34	3.26	3.00	.994	267	3.69	4.00	.878
Thinking about thinking	84	3.68	4.00	.824	150	3.73	4.00	.858	34	3.59	4.00	.821	268	3.69	4.00	.841
Recognizing cues	83	3.86	4.00	.813	152	3.84	4.00	.872	34	3.71	4.00	.629	269	3.83	4.00	.826
Judging the credibility of a source	84	3.77	4.00	.797	151	3.97	4.00	.770	34	4.03	4.00	.521	269	3.91	4.00	.756

Variables	Program level															
	Certificate/diploma				Associate degree				Bachelors degree				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Adapting protocols based on analysis of a situation	82	4.37	4.00	.619	151	4.36	4.00	.636	34	4.15	4.00	.657	267	4.33	4.00	.635
Reasoning to make decisions, diagnose problems, project outcomes	84	4.44	4.00	.499	152	4.51	5.00	.515	34	4.41	4.00	.557	270	4.47	4.00	.515
Growing sense of responsibility for patient outcomes	83	3.94	4.00	.771	151	3.96	4.00	.886	34	3.94	4.00	.983	268	3.95	4.00	.862

Table 4: Descriptive Summary (by highest degree) Critical Thinking attributes – Part D

Variables	Program director – highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Empathizing	30	2.70	3.00	1.055	230	2.83	3.00	1.034	8	2.88	2.50	.991	268	2.81	3.00	1.033
Deductive reasoning	30	4.20	4.00	.407	232	4.20	4.00	.613	8	4.13	4.00	.354	270	4.20	4.00	.587
Inductive reasoning	29	4.07	4.00	.530	231	4.06	4.00	.643	8	4.00	4.00	.535	268	4.06	4.00	.627
Problem-solving	30	4.37	4.00	.615	231	4.40	4.00	.565	8	4.38	4.00	.518	269	4.39	4.00	.567
Following protocols	29	2.59	2.00	1.018	229	2.79	3.00	.997	8	2.50	3.00	.756	266	2.76	3.00	.993
Planning	29	3.69	4.00	.891	229	3.73	4.00	.865	8	3.50	4.00	.756	266	3.72	4.00	.863
Sensing (seeing, touching, hearing)	30	3.13	3.00	1.008	229	3.43	4.00	.978	8	3.50	4.00	.756	267	3.40	4.00	.977
Speaking or writing	30	3.17	3.00	1.053	227	3.46	4.00	.903	8	3.25	3.00	.886	265	3.42	4.00	.922
Using clinical judgment	30	4.30	4.00	.651	232	4.42	4.00	.583	8	4.38	4.00	.518	270	4.40	4.00	.588
Defending an opinion	30	3.93	4.00	.785	229	3.92	4.00	.826	8	3.50	3.50	.535	267	3.91	4.00	.815
Applying reflective skepticism	30	3.87	4.00	.819	229	3.85	4.00	.693	8	3.75	4.00	.463	267	3.85	4.00	.701
Judging evidence to be more or less important	30	4.03	4.00	.669	230	4.00	4.00	.718	8	4.00	4.00	.535	268	4.00	4.00	.706
Interrogating, cross-examining	30	3.87	4.00	.819	231	3.66	4.00	.870	8	3.63	4.00	.518	269	3.68	4.00	.856
Thinking creatively	30	4.00	4.00	.830	232	4.14	4.00	.691	8	4.38	4.00	.518	270	4.13	4.00	.704
Motivating others	30	3.50	4.00	1.196	231	3.40	4.00	.926	8	3.38	3.00	.916	269	3.41	4.00	.956

Variables	Program director – highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Managing others	30	3.47	4.00	1.074	230	3.53	4.00	.894	8	3.25	3.00	.886	268	3.52	4.00	.914
Using higher cognitive thinking	30	4.17	4.00	.592	229	4.26	4.00	.663	8	4.00	4.00	.535	267	4.24	4.00	.652
Reading	30	3.30	3.00	1.055	231	3.25	3.00	.954	8	3.50	4.00	.756	269	3.26	3.00	.959
Communicating verbally	30	3.37	4.00	1.098	231	3.55	4.00	.976	7	3.86	4.00	.690	268	3.54	4.00	.984
Exploring ethical issues impacting a solution	29	4.21	4.00	.675	227	4.19	4.00	.663	8	4.00	4.00	.535	264	4.19	4.00	.660
Interpreting data on a table or graph	30	3.77	4.00	.935	230	3.64	4.00	.844	8	3.63	4.00	.518	268	3.65	4.00	.845
Exercising reflective reasoning	30	4.10	4.00	.845	232	4.06	4.00	.678	8	3.75	4.00	.463	270	4.05	4.00	.693
Reasoning intuitively	30	3.73	4.00	.907	229	3.88	4.00	.873	8	3.75	4.00	.886	267	3.86	4.00	.875
Performing routine procedures	30	2.83	3.00	1.177	230	3.08	3.00	1.044	8	2.75	3.00	1.035	268	3.04	3.00	1.059
Conducting research in a discipline	30	3.93	4.00	.785	230	3.63	4.00	.911	8	3.63	3.50	.744	268	3.66	4.00	.895
Implementing a plan	30	3.43	4.00	1.073	229	3.72	4.00	.858	8	3.50	3.50	.535	267	3.69	4.00	.879
Thinking about thinking	29	3.66	4.00	1.010	231	3.70	4.00	.831	8	3.50	4.00	.756	268	3.69	4.00	.847
Recognizing cues	30	3.67	4.00	.959	231	3.84	4.00	.816	8	3.88	4.00	.641	269	3.82	4.00	.827
Judging the credibility of a source	30	4.17	4.00	.461	231	3.88	4.00	.785	8	3.88	4.00	.641	269	3.91	4.00	.756

Variables	Program director – highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Adapting protocols based on analysis of a situation	30	4.30	4.00	.535	229	4.35	4.00	.649	8	4.00	4.00	.535	267	4.33	4.00	.635
Reasoning to make decisions, diagnose problems, project outcomes	30	4.43	4.00	.504	232	4.49	4.50	.518	8	4.13	4.00	.354	270	4.47	4.00	.515
Growing sense of responsibility for patient outcomes	30	3.93	4.00	.868	230	3.94	4.00	.872	8	4.13	4.00	.641	268	3.95	4.00	.864

Table 5: Descriptive Summary Teaching Strategies (by program level)

Variables	Effective teaching strategies by program level															
	Program level															
	Certificate/diploma				Associate degree				Bachelors degree				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Socratic questioning	85	3.68	4.00	.759	149	3.76	4.00	.802	33	3.82	4.00	.882	267	3.74	4.00	.797
On-line discussions	85	3.32	3.00	.848	148	3.49	4.00	.877	32	3.53	4.00	.803	265	3.44	4.00	.860
In class discussions	84	4.35	4.00	.611	153	4.28	4.00	.519	34	4.21	4.00	.592	271	4.29	4.00	.558
Traditional lectures	83	3.31	4.00	.987	152	3.26	3.00	.959	34	3.18	3.00	1.114	269	3.26	3.00	.985
Clinical case studies	84	4.29	4.00	.737	152	4.38	4.00	.551	34	4.44	4.00	.561	270	4.36	4.00	.616
Reflective journaling	84	3.75	4.00	.903	151	3.72	4.00	.842	34	4.06	4.00	.547	269	3.77	4.00	.836
Concept mapping	83	3.66	4.00	.769	151	3.73	4.00	.783	32	3.75	4.00	.672	266	3.71	4.00	.764
High order multiple choice test items	84	3.81	4.00	.784	152	3.97	4.00	.727	34	4.18	4.00	.716	270	3.95	4.00	.750
Situational judgment test items	84	4.25	4.00	.578	151	4.41	4.00	.545	34	4.24	4.00	.554	269	4.34	4.00	.561
Role playing	84	4.18	4.00	.747	153	4.24	4.00	.698	34	4.03	4.00	.797	271	4.20	4.00	.727
Case based learning	83	4.19	4.00	.689	150	4.21	4.00	.698	34	4.15	4.00	.657	267	4.19	4.00	.688
Problem based learning	84	4.30	4.00	.555	152	4.38	4.00	.597	34	4.35	4.00	.544	270	4.35	4.00	.577
Collaborative learning	83	4.10	4.00	.637	151	4.06	4.00	.741	34	4.18	4.00	.758	268	4.09	4.00	.711
Portfolios	81	3.38	3.00	.860	145	3.26	3.00	.921	31	3.39	3.00	.955	257	3.32	3.00	.905

Table 6: Descriptive Summary Teaching Strategies (by highest degree)

Variables	Effective teaching strategies by program level															
	Highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Dev	N	Mean	Median	Std. Dev	N	Mean	Median	Std. Dev	N	Mean	Median	Std. Dev
Socratic questioning	30	3.70	4.00	.915	228	3.74	4.00	.790	8	3.88	4.00	.641	266	3.74	4.00	.799
On-line discussions	29	3.90	4.00	.673	227	3.39	4.00	.872	8	3.25	3.00	.707	264	3.44	4.00	.861
In class discussions	30	4.30	4.00	.466	232	4.30	4.00	.575	8	4.13	4.00	.354	270	4.29	4.00	.558
Traditional lectures	30	3.03	3.00	.964	230	3.30	3.00	.984	8	3.00	3.00	1.069	268	3.26	3.00	.985
Clinical case studies	30	4.30	4.00	.535	231	4.38	4.00	.633	8	4.13	4.00	.354	269	4.36	4.00	.617
Reflective journaling	30	4.10	4.00	.759	230	3.73	4.00	.850	8	3.87	4.00	.354	268	3.78	4.00	.836
Concept mapping	30	3.93	4.00	.740	227	3.69	4.00	.767	8	3.38	3.50	.744	265	3.71	4.00	.766
High order multiple choice test items	30	4.00	4.00	.743	231	3.94	4.00	.763	8	4.13	4.00	.354	269	3.95	4.00	.751
Situational judgment test items	30	4.40	4.00	.563	230	4.34	4.00	.567	8	4.13	4.00	.354	268	4.34	4.00	.561
Role playing	30	4.37	4.00	.556	232	4.18	4.00	.755	8	4.13	4.00	.354	270	4.20	4.00	.728
Case based learning	30	4.33	4.00	.711	228	4.19	4.00	.686	8	3.88	4.00	.641	266	4.20	4.00	.689
Problem based learning	30	4.43	4.00	.568	231	4.35	4.00	.578	8	4.00	4.00	.535	269	4.35	4.00	.578
Collaborative learning	30	3.97	4.00	.890	229	4.11	4.00	.692	8	3.63	4.00	.518	267	4.08	4.00	.716
Portfolios	28	3.29	3.00	.763	220	3.31	3.00	.930	8	3.38	3.50	.744	256	3.31	3.00	.905

Table 7: Descriptive Summary Utilization of Teaching Strategies (by program level)

Variables	Utilization of teaching strategies by program level															
	Program level															
	Certificate/diploma				Associate degree				Bachelors degree				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Socratic questioning	70	3.13	3.00	1.560	125	3.38	3.00	1.342	27	4.00	4.00	1.593	222	3.37	3.00	1.461
On-line discussions	84	1.50	1.00	1.036	145	2.30	2.00	1.208	33	2.45	2.00	1.277	262	2.06	2.00	1.224
In class discussions	84	4.73	5.00	1.186	147	4.75	5.00	1.169	33	4.55	5.00	1.092	264	4.72	5.00	1.163
Traditional lectures	83	4.94	5.00	1.119	148	4.73	5.00	1.187	33	4.79	5.00	1.139	264	4.80	5.00	1.160
Clinical case studies	85	4.12	4.00	1.349	146	3.88	4.00	1.251	32	3.91	4.00	1.088	263	3.96	4.00	1.266
Reflective journaling	84	2.33	2.00	1.531	143	2.64	2.00	1.412	32	2.66	2.50	1.234	259	2.54	2.00	1.434
Concept mapping	80	2.15	2.00	1.415	141	2.35	2.00	1.493	30	2.23	2.00	1.194	251	2.27	2.00	1.433
High order multiple choice test items	82	4.62	5.00	1.339	146	4.75	5.00	1.197	32	4.66	4.50	1.234	260	4.70	5.00	1.244
Situational judgment test items	85	3.80	4.00	1.470	148	3.82	4.00	1.393	33	3.45	3.00	1.348	266	3.77	4.00	1.413
Role playing	84	3.40	3.00	1.599	149	3.50	3.00	1.482	33	2.82	3.00	1.261	266	3.39	3.00	1.506
Case based learning	84	3.50	3.00	1.427	144	3.53	3.50	1.384	33	3.27	3.00	1.153	261	3.49	3.00	1.369
Problem based learning	85	4.07	4.00	1.378	148	4.03	4.00	1.330	32	3.50	3.00	1.295	265	3.98	4.00	1.348
Collaborative learning	84	4.00	4.00	1.456	145	3.84	4.00	1.403	33	3.52	3.00	1.302	262	3.85	4.00	1.410
Portfolios	83	2.04	1.00	1.460	138	2.20	2.00	1.490	31	2.19	2.00	1.167	252	2.15	2.00	1.442

Table 8: Descriptive Summary Utilization of Teaching Strategies (by highest degree)

Utilization of teaching strategies by highest degree

Variables	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Socratic questioning	27	3.44	3.00	1.476	188	3.38	3.00	1.474	7	2.57	2.00	1.272	222	3.36	3.00	1.469
On-line discussions	30	2.70	2.50	1.557	224	1.99	2.00	1.168	8	1.50	1.50	.535	262	2.06	2.00	1.226
In class discussions	29	4.72	5.00	1.162	226	4.74	5.00	1.146	8	3.88	3.50	1.458	263	4.71	5.00	1.162
Traditional lectures	30	4.63	5.00	1.129	225	4.84	5.00	1.153	8	4.38	5.00	1.506	263	4.81	5.00	1.161
Clinical case studies	29	4.21	4.00	1.236	225	3.95	4.00	1.269	8	3.13	3.50	1.126	262	3.95	4.00	1.268
Reflective journaling	28	2.75	2.00	1.351	223	2.53	2.00	1.457	8	2.25	2.00	1.035	259	2.54	2.00	1.434
Concept mapping	27	2.52	2.00	1.528	217	2.25	2.00	1.438	7	1.71	2.00	.756	251	2.26	2.00	1.435
High order multiple choice test items	29	4.66	5.00	1.203	223	4.71	5.00	1.238	8	4.62	5.00	1.685	260	4.70	5.00	1.244
Situational judgment test items	30	3.70	3.50	1.489	227	3.77	4.00	1.415	8	3.50	4.00	1.414	265	3.75	4.00	1.419
Role playing	30	3.40	3.00	1.694	227	3.37	3.00	1.474	8	3.50	3.50	1.852	265	3.38	3.00	1.505
Case based learning	29	3.62	3.00	1.425	224	3.49	3.00	1.372	8	2.75	3.00	1.035	261	3.48	3.00	1.372
Problem based learning	30	4.10	4.00	1.373	226	3.97	4.00	1.351	8	3.38	3.50	1.408	264	3.97	4.00	1.355
Collaborative learning	30	3.87	4.00	1.479	223	3.87	4.00	1.403	8	3.00	3.00	1.309	261	3.84	4.00	1.412
Portfolios	28	2.18	2.00	1.156	217	2.15	1.00	1.490	7	1.86	2.00	.690	252	2.14	2.00	1.438

Table 9: Descriptive Summary - Appropriateness of assessment measures (by program level)

Variables	Program level: Certificate/diploma N	Mean	Median	Std. Deviation	Associate degree N	Mean	Median	Std. Deviation	Bachelors degree N	Mean	Median	Std. Deviation	Total N	Mean	Median	Std. Deviation
Course exam results	85	3.52	4.00	.946	151	3.64	4.00	.819	33	3.30	4.00	1.045	269	3.56	4.00	.894
ARRT exam results	85	3.35	3.00	1.020	152	3.48	4.00	.949	34	2.85	3.00	1.184	271	3.36	4.00	1.019
Clinical competency results	85	4.31	4.00	.535	153	4.29	4.00	.713	34	3.76	4.00	.741	272	4.23	4.00	.687
Image critique performance	85	4.36	4.00	.531	152	4.38	4.00	.597	34	4.24	4.00	.654	271	4.36	4.00	.585
Specific course assignments	84	4.00	4.00	.677	153	4.07	4.00	.685	33	3.91	4.00	.843	270	4.03	4.00	.703
Situational judgment test items	85	4.15	4.00	.588	152	4.28	4.00	.603	34	3.94	4.00	.600	271	4.20	4.00	.606
Portfolios	85	3.06	3.00	.980	150	3.01	3.00	.955	32	3.06	3.00	1.105	267	3.03	3.00	.979
Reflective Journals	85	3.34	3.00	.995	151	3.34	3.00	.959	31	3.39	4.00	1.054	267	3.35	3.00	.978
Clinical case study performance	83	4.14	4.00	.497	151	4.10	4.00	.746	34	4.06	4.00	.600	268	4.11	4.00	.659
Employer surveys	85	3.66	4.00	.880	152	3.43	4.00	.960	34	3.12	3.00	1.008	271	3.46	4.00	.953
Student surveys	85	3.47	4.00	.867	152	3.27	3.00	.976	34	2.97	3.00	.969	271	3.30	3.00	.951
Standardized test results (such as the WGCTA or CCTST)	82	2.96	3.00	.793	145	2.95	3.00	.691	32	2.78	3.00	.751	259	2.93	3.00	.731

Table 10: Descriptive Summary - Appropriateness of assessment measures (by highest degree)

Variables	Program director - highest degree															
	Doctoral				Masters				Bachelors				Total			
	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation	N	Mean	Median	Std. Deviation
Course exam results	30	3.50	4.00	.820	230	3.57	4.00	.912	8	3.50	4.00	.756	268	3.56	4.00	.896
ARRT exam results	30	3.40	4.00	1.037	232	3.38	4.00	1.012	8	2.63	2.50	1.061	270	3.36	4.00	1.020
Clinical competency results	30	4.07	4.00	.691	233	4.25	4.00	.695	8	4.13	4.00	.354	271	4.23	4.00	.688
Image critique performance	30	4.27	4.00	.640	232	4.38	4.00	.577	8	4.00	4.00	.535	270	4.36	4.00	.585
Specific course assignments	30	4.13	4.00	.629	231	4.02	4.00	.719	8	3.87	4.00	.354	269	4.03	4.00	.701
Situational judgment test items	30	4.20	4.00	.551	232	4.21	4.00	.612	8	3.88	4.00	.641	270	4.20	4.00	.607
Portfolios	29	3.21	3.00	.940	229	3.03	3.00	.982	8	2.75	2.50	1.165	266	3.04	3.00	.982
Reflective Journals	29	3.59	4.00	1.086	229	3.32	3.00	.977	8	3.38	3.00	.518	266	3.35	3.00	.980
Clinical case study performance	30	4.13	4.00	.681	229	4.12	4.00	.655	8	3.75	4.00	.707	267	4.11	4.00	.660
Employer surveys	30	3.43	4.00	1.006	232	3.46	4.00	.952	8	3.63	4.00	.916	270	3.46	4.00	.954
Student surveys	30	3.33	4.00	.994	232	3.29	3.00	.953	8	3.12	3.00	.835	270	3.29	3.00	.951
Standardized test results (such as the WGCTA or CCTST)	28	2.86	3.00	.705	222	2.94	3.00	.740	8	3.00	3.00	.535	258	2.93	3.00	.729

Table 11: Descriptive Summary Utilization of Assessment Measures (by program level)

	Certificate/diploma				Associate degree				Bachelors degree				Total		
	N	Sum	% of Total Sum	% of group N	N	Sum	% of Total Sum	% of group N	N	Sum	% of Total Sum	% of group N	N	Sum	% of group N
Course exam results	85	40	32.0%	47.1%	155	72	57.6%	46.5%	34	13	10.4%	38.2%	274	125	45.6%
ARRT exam results	85	49	35.8%	57.6%	155	75	54.7%	48.4%	34	13	9.5%	38.2%	274	137	50.0%
Clinical competency results	85	73	33.2%	85.9%	155	123	55.9%	79.4%	34	24	10.9%	70.6%	274	220	80.3%
Image critique performance	85	62	34.4%	72.9%	155	99	55.0%	63.8%	34	19	10.6%	55.9%	274	180	65.7%
Specific course assignments	85	57	35.0%	67.1%	155	89	54.6%	57.4%	34	17	10.4%	50.0%	274	163	59.5%
Situational judgment test items	85	31	36.5%	36.5%	155	45	52.9%	29.0%	34	9	10.6%	26.5%	274	85	31.0%
Portfolios	85	12	33.3%	14.1%	155	20	55.6%	12.9%	34	4	11.1%	11.8%	274	36	13.1%
Reflective Journals	85	11	28.9%	12.9%	155	23	60.5%	14.8%	34	4	10.5%	11.8%	274	38	13.9%
Clinical case study performance	85	28	28.0%	32.9%	155	57	57.0%	36.8%	34	15	15.0%	44.1%	274	100	36.5%
Employer surveys	85	66	35.3%	77.6%	155	102	54.5%	65.8%	34	19	10.2%	55.9%	274	187	68.2%
Student surveys	85	53	35.1%	62,4%	155	83	55.0%	53.5%	34	15	9.9%	44.1%	274	151	55.1%
Standardized test (such as the WGCTA or CCTST)	85	2	28.6%	2.3%	155	4	57.1%	2.6%	34	1	14.3%	2.9%	274	7	2.6%

Table 12: Descriptive Summary Utilization of Assessment Measures (by highest degree)

	Doctors degree				Masters degree				Bachelors degree						
	N	Sum	% of Total Sum	% of Group N	N	Sum	% of Total Sum	% of Group N	N	Sum	% of Total Sum	% of Group N	N	Sum	% of Total N
Course exam results	30	14	11.3%	46.7%	235	105	84.7%	44.6%	8	5	4.0%	62.5%	273	124	45.4%
ARRT exam results	30	13	9.6%	43.3%	235	119	88.1%	50.6%	8	3	2.2%	37.5%	273	135	49.5%
Clinical competency results	30	22	10.0%	73.3%	235	191	87.2%	81.3%	8	6	2.7%	75.0%	273	219	80.2%
Image critique performance	30	16	8.9%	53.3%	235	158	87.8%	67.2%	8	6	3.3%	75.0%	273	180	65.9%
Specific course assignments	30	23	14.1%	76.7%	235	136	83.4%	57.8%	8	4	2.5%	50.0%	273	163	59.7%
Situational judgment test items	30	9	10.7%	30.0%	235	73	86.9%	31.1%	8	2	2.4%	25.0%	273	84	30.7%
Portfolios	30	4	10.8%	13.3%	235	31	83.8%	13.2%	8	2	5.4%	25.0%	273	37	13.6%
Reflective Journals	30	6	15.8%	20.0%	235	32	84.2%	13.6%	8	0	.0%	0.0%	273	38	13.9%
Clinical case study performance	30	11	11.1%	36.7%	235	88	88.9%	37.4%	8	0	.0%	0.0%	273	99	36.3%
Employer surveys	30	15	8.1%	50.0%	235	165	89.2%	70.2%	8	5	2.7%	62.5%	273	185	67.7%
Student surveys	30	13	8.7%	43.3%	235	133	89.3%	56.6%	8	3	2.0%	37.5%	273	149	54.6%
Standardized test (such as the WGCTA or CCTST)	30	0	.0%	0.0%	235	6	100.0%	2.6%	8	0	.0%	0.0%	273	6	2.2%

APPENDIX H
CHI SQUARE ANALYSES AND EFFECT SIZE

Table 1: Chi square analysis - Critical thinking definition by program level – Part A

Variable	**Ranks**			**Kruskal - Wallis**			**Effect size**
	Program level	**N**	**Mean Rank**	**Chi-square**	**df**	**p**	**Cramer's V**
Critical thinking is a vital skill for radiographers	Certificate/diploma	84	135.74	1.709	2	.425	.069
	Associate degree	154	139.07				
	Bachelors degree	34	126.74				
	Total	272					
Critical thinking must be included in radiologic sciences educational programs	Certificate/diploma	84	129.15	1.761	2	.415	.115
	Associate degree	154	139.97				
	Bachelors degree	34	138.93				
	Total	272					
Radiologic sciences programs generally do a good job teaching critical thinking	Certificate/diploma	82	135.79	.358	2	.836	.056
	Associate degree	153	136.12				
	Bachelors degree	34	128.07				
	Total	269					
Critical thinking is a generalizable skill (can be applied to many different activities)	Certificate/diploma	84	140.89	.763	2	.683	.098
	Associate degree	154	132.81				
	Bachelors degree	33	138.44				
	Total	271					
A critical thinker in radiography may not be a critical thinker in other (non-health care)areas or activities	Certificate/diploma	82	147.15	7.783	2	.020	.161
	Associate degree	153	135.20				
	Bachelors degree	34	104.82				
	Total	269					
Clinical reasoning and critical thinking are synonymous	Certificate/diploma	84	129.69	.998	2	.607	.078
	Associate degree	154	139.65				
	Bachelors degree	33	135.02				
	Total	271					
Critical thinking is an abstract cognitive activity	Certificate/diploma	81	133.79	1.223	2	.543	.145
	Associate degree	150	135.43				
	Bachelors degree	34	120.38				
	Total	265					
Critical thinking is a linear process	Certificate/diploma	83	140.05	2.710	2	.258	.103
	Associate degree	154	138.14				
	Bachelors degree	34	116.43				
	Total	271					
Critical thinking and following protocol are synonymous	Certificate/diploma	84	129.11	7.483	2	.024	.159
	Associate degree	153	145.24				
	Bachelors degree	34	111.46				
	Total	271					
Critical thinking is best acquired in liberal arts, non health professions courses	Certificate/diploma	83	149.85	6.866	2	.032	.148
	Associate degree	154	133.40				
	Bachelors degree	34	113.99				
	Total	271					
Critical thinking in radiography may be conceptually different than critical thinking in other health care disciplines	Certificate/diploma	83	142.87	1.442	2	.486	.131
	Associate degree	153	132.26				
	Bachelors degree	33	127.91				
	Total	269					

Variable	Ranks			Kruskal - Wallis			Effect size
	Program level	N	Mean Rank	Chi-square	df	p	Cramer's V
Critical thinking is a rational process	Certificate/diploma	81	124.51	2.974	2	.226	.102
	Associate degree	152	139.81				
	Bachelors degree	34	130.66				
	Total	267					
Critical thinking is a series of decisions made by the radiographer in the clinical setting	Certificate/diploma	84	143.57	3.208	2	.201	.149
	Associate degree	154	136.58				
	Bachelors degree	34	118.69				
	Total	272					
Critical thinking can be learned	Certificate/diploma	84	140.51	1.122	2	.571	.130
	Associate degree	153	135.63				
	Bachelors degree	34	126.53				
	Total	271					
A standard model or definition for critical thinking is needed in radiologic sciences	Certificate/diploma	84	137.75	.491	2	.782	.096
	Associate degree	153	136.87				
	Bachelors degree	34	127.78				
	Total	271					
Critical thinking is synonymous with decision making processes	Certificate/diploma	83	142.48	3.043	2	.218	.143
	Associate degree	154	135.72				
	Bachelors degree	33	116.92				
	Total	270					
Problem-solving and critical thinking are synonymous	Certificate/diploma	84	142.42	1.757	2	.415	.098
	Associate degree	151	133.11				
	Bachelors degree	34	125.09				
	Total	269					
Graduates of your program have well-developed critical thinking skills when entering their first radiography job	Certificate/diploma	84	144.34	1.693	2	.429	.103
	Associate degree	154	133.16				
	Bachelors degree	34	132.25				
	Total	272					

Table 2: Chi square analysis - Critical thinking definition by program level – Part D

Variables	Ranks			Kruskal - Wallis			Effect size
	Program level	**N**	**Mean Rank**	**Chi-square**	**df**	**p**	**Cramer's V**
Empathizing	Certificate/diploma	83	148.27	4.703	2	.095	.114
	Associate degree	151	130.33				
	Bachelors degree	34	119.41				
	Total	268					
Deductive reasoning	Certificate/diploma	84	133.92	1.656	2	.437	.108
	Associate degree	152	138.98				
	Bachelors degree	34	123.85				
	Total	270					
Inductive reasoning	Certificate/diploma	84	128.95	1.762	2	.414	.090
	Associate degree	151	134.92				
	Bachelors degree	33	146.70				
	Total	268					
Problem-solving	Certificate/diploma	84	132.66	1.182	2	.554	.112
	Associate degree	151	138.47				
	Bachelors degree	34	125.38				
	Total	269					
Following protocols	Certificate/diploma	84	146.81	6.556	2	.038	.131
	Associate degree	148	131.49				
	Bachelors degree	34	109.38				
	Total	266					
Planning	Certificate/diploma	84	144.15	3.212	2	.201	.084
	Associate degree	149	128.43				
	Bachelors degree	33	129.27				
	Total	266					
Sensing (seeing, touching, hearing)	Certificate/diploma	84	137.04	2.505	2	.286	.127
	Associate degree	149	136.48				
	Bachelors degree	34	115.63				
	Total	267					
Speaking or writing	Certificate/diploma	84	141.45	1.757	2	.416	.123
	Associate degree	148	129.69				
	Bachelors degree	33	126.32				
	Total	265					
Using clinical judgment	Certificate/diploma	84	139.49	3.077	2	.215	.134
	Associate degree	152	137.55				
	Bachelors degree	34	116.47				
	Total	270					
Defending an opinion	Certificate/diploma	83	133.31	.062	2	.970	.135
	Associate degree	150	133.76				
	Bachelors degree	34	136.74				
	Total	267					
Applying reflective skepticism	Certificate/diploma	83	132.55	.328	2	.849	.147
	Associate degree	150	133.42				
	Bachelors degree	34	140.09				
	Total	267					

Variables	Ranks			Kruskal - Wallis			Effect size
	Program level	**N**	**Mean Rank**	**Chi-square**	**df**	**p**	**Cramer's V**
Judging evidence to be more or less important	Certificate/diploma	83	141.28	2.523	2	.283	.106
	Associate degree	151	134.04				
	Bachelors degree	34	120.00				
	Total	268					
Interrogating, cross-examining	Certificate/diploma	84	128.89	.997	2	.608	.143
	Associate degree	151	138.56				
	Bachelors degree	34	134.28				
	Total	269					
Thinking creatively	Certificate/diploma	84	139.57	1.295	2	.523	.135
	Associate degree	152	135.86				
	Bachelors degree	34	123.87				
	Total	270					
Motivating others	Certificate/diploma	84	142.79	1.369	2	.504	.182
	Associate degree	151	131.42				
	Bachelors degree	34	131.68				
	Total	269					
Managing others	Certificate/diploma	83	140.62	1.070	2	.586	.144
	Associate degree	151	132.95				
	Bachelors degree	34	126.44				
	Total	268					
Using higher cognitive thinking	Certificate/diploma	83	136.23	.385	2	.825	.097
	Associate degree	151	131.81				
	Bachelors degree	33	138.39				
	Total	267					
Reading	Certificate/diploma	84	135.42	3.216	2	.200	.123
	Associate degree	151	130.18				
	Bachelors degree	34	155.37				
	Total	269					
Communicating verbally	Certificate/diploma	84	135.46	.031	2	.985	.131
	Associate degree	150	133.80				
	Bachelors degree	34	135.22				
	Total	268					
Exploring ethical issues impacting a solution	Certificate/diploma	82	136.63	.517	2	.772	.158
	Associate degree	148	130.18				
	Bachelors degree	34	132.66				
	Total	264					
Interpreting data on a table or graph	Certificate/diploma	83	134.97	.737	2	.692	.121
	Associate degree	151	132.17				
	Bachelors degree	34	143.69				
	Total	268					
Exercising reflective reasoning	Certificate/diploma	84	145.46	2.698	2	.260	.104
	Associate degree	152	131.32				
	Bachelors degree	34	129.57				
	Total	270					

Variables	Ranks			Kruskal - Wallis			Effect size
	Program level	N	Mean Rank	Chi-square	df	p	Cramer's V
Reasoning intuitively	Certificate/diploma	83	144.99	3.187	2	.203	.079
	Associate degree	150	130.06				
	Bachelors degree	34	124.54				
	Total	267					
Performing routine procedures	Certificate/diploma	83	138.89	1.309	2	.520	.132
	Associate degree	151	134.99				
	Bachelors degree	34	121.60				
	Total	268					
Conducting research in a discipline	Certificate/diploma	84	134.99	1.145	2	.564	.136
	Associate degree	151	131.65				
	Bachelors degree	33	146.29				
	Total	268					
Implementing a plan	Certificate/diploma	84	142.70	8.802	2	.012	.115
	Associate degree	149	136.53				
	Bachelors degree	34	101.43				
	Total	267					
Thinking about thinking	Certificate/diploma	84	133.43	.550	2	.760	.117
	Associate degree	150	136.80				
	Bachelors degree	34	127.00				
	Total	268					
Recognizing cues	Certificate/diploma	83	138.93	2.196	2	.334	.132
	Associate degree	152	136.49				
	Bachelors degree	34	118.74				
	Total	269					
Judging the credibility of a source	Certificate/diploma	84	123.88	3.377	2	.185	.136
	Associate degree	151	139.61				
	Bachelors degree	34	142.01				
	Total	269					
Adapting protocols based on analysis of a situation	Certificate/diploma	82	137.39	3.449	2	.178	.092
	Associate degree	151	136.72				
	Bachelors degree	34	113.76				
	Total	267					
Reasoning to make decisions, diagnose problems, project outcomes	Certificate/diploma	84	130.52	1.419	2	.492	.099
	Associate degree	152	139.80				
	Bachelors degree	34	128.56				
	Total	270					
Growing sense of responsibility for patient outcomes	Certificate/diploma	83	130.82	.317	2	.854	.105
	Associate degree	151	136.25				
	Bachelors degree	34	135.72				
	Total	268					

Table 3: Chi square analysis - Critical thinking definition by highest degree – Part A

Variables	**Ranks**			**Kruskal - Wallis**			**Effect size**
	Highest degree	**N**	**Mean Rank**	**Chi-square**	**df**	**p**	**Cramer's V**
Critical thinking is a vital skill for radiographers	Doctoral	30	**140.07**	.329	2	.848	.031
	Masters	233	135.30				
	Bachelors	8	141.19				
	Total	271					
Critical thinking must be included in radiologic sciences educational programs	Doctoral	30	138.30	.099	2	.952	.047
	Masters	233	135.55				
	Bachelors	8	140.50				
	Total	271					
Radiologic sciences programs generally do a good job teaching critical thinking	Doctoral	30	133.30	1.737	2	.420	.109
	Masters	230	135.80				
	Bachelors	8	101.69				
	Total	268					
Critical thinking is a generalizable skill (can be applied to many different activities)	Doctoral	30	152.10	2.397	2	.302	.081
	Masters	232	132.83				
	Bachelors	8	150.75				
	Total	270					
A critical thinker in radiography may not be a critical thinker in other (non-health care)areas or activities	Doctoral	30	116.98	1.886	2	.389	.127
	Masters	230	136.67				
	Bachelors	8	137.69				
	Total	268					
Clinical reasoning and critical thinking are synonymous	Doctoral	30	119.33	2.363	2	.307	.083
	Masters	232	138.28				
	Bachelors	8	115.50				
	Total	270					
Critical thinking is an abstract cognitive activity	Doctoral	29	110.71	3.072	2	.215	.106
	Masters	227	134.94				
	Bachelors	8	142.31				
	Total	264					
Critical thinking is a linear process	Doctoral	30	129.85	.211	2	.900	.067
	Masters	232	136.32				
	Bachelors	8	132.88				
	Total	270					
Critical thinking and following protocol are synonymous	Doctoral	30	127.68	.495	2	.781	.090
	Masters	232	136.72				
	Bachelors	8	129.38				
	Total	270					

Variables	Ranks			Kruskal - Wallis			Effect size
	Highest degree	N	Mean Rank	Chi-square	df	p	Cramer's V
Critical thinking is best acquired in liberal arts, non health professions courses	Doctoral	30	127.17	1.629	2	.443	.099
	Masters	232	135.65				
	Bachelors	8	162.50				
	Total	270					
Critical thinking in radiography may be conceptually different than critical thinking in other health care disciplines	Doctoral	30	127.70	3.399	2	.183	.151
	Masters	230	136.93				
	Bachelors	8	90.00				
	Total	268					
Critical thinking is a rational process	Doctoral	30	132.00	.036	2	.982	.106
	Masters	229	133.59				
	Bachelors	7	137.00				
	Total	266					
Critical thinking is a series of decisions made by the radiographer in the clinical setting	Doctoral	30	137.47	.558	2	.757	.072
	Masters	233	136.42				
	Bachelors	8	118.38				
	Total	271					
Critical thinking can be learned	Doctoral	30	145.03	.774	2	.679	.104
	Masters	232	134.49				
	Bachelors	8	129.00				
	Total	270					
A standard model or definition for critical thinking is needed in radiologic sciences	Doctoral	30	127.98	2.219	2	.330	.109
	Masters	233	135.32				
	Bachelors	7	173.79				
	Total	270					
Critical thinking is synonymous with decision making processes	Doctoral	30	123.18	.938	2	.626	.085
	Masters	231	136.48				
	Bachelors	8	136.50				
	Total	269					
Problem-solving and critical thinking are synonymous	Doctoral	30	110.53	4.224	2	.121	.141
	Masters	230	137.90				
	Bachelors	8	126.50				
	Total	268					
Graduates of your program have well-developed critical thinking skills when entering their first radiography job	Doctoral	30	133.60	6.447	2	.040	.152
	Masters	233	138.30				
	Bachelors	8	77.94				
	Total	271					

Table 4: Chi square analysis - Critical thinking definition by highest degree – Part D

Variables	Ranks			Kruskal - Wallis			Effect size
	Highest degree	N	Mean Rank	Chi-square	df	p	Cramer's V
Empathizing	Doctoral	30	127.70	.291	2	.865	.105
	Masters	230	135.27				
	Bachelors	8	137.88				
	Total	268					
Deductive reasoning	Doctoral	30	132.10	.464	2	.793	.094
	Masters	232	136.39				
	Bachelors	8	122.50				
	Total	270					
Inductive reasoning	Doctoral	29	133.71	.147	2	.929	.057
	Masters	231	134.89				
	Bachelors	8	126.00				
	Total	268					
Problem-solving	Doctoral	30	132.70	.087	2	.957	.095
	Masters	231	135.47				
	Bachelors	8	130.13				
	Total	269					
Following protocols	Doctoral	29	122.40	1.100	2	.577	.131
	Masters	229	135.39				
	Bachelors	8	119.69				
	Total	266					
Planning	Doctoral	29	129.81	1.218	2	.544	.097
	Masters	229	134.80				
	Bachelors	8	109.75				
	Total	266					
Sensing (seeing, touching, hearing)	Doctoral	30	114.77	2.396	2	.302	.098
	Masters	229	136.30				
	Bachelors	8	140.19				
	Total	267					
Speaking or writing	Doctoral	30	113.48	3.402	2	.182	.142
	Masters	227	136.34				
	Bachelors	8	111.50				
	Total	265					
Using clinical judgment	Doctoral	30	125.13	.893	2	.640	.136
	Masters	232	137.07				
	Bachelors	8	128.81				
	Total	270					
Defending an opinion	Doctoral	30	136.33	3.418	2	.181	.121
	Masters	229	135.27				
	Bachelors	8	89.00				
	Total	267					
Applying reflective skepticism	Doctoral	30	137.60	.359	2	.836	.107
	Masters	229	133.96				
	Bachelors	8	121.63				
	Total	267					

Variables	Ranks			Kruskal - Wallis			Effect size
	Highest degree	N	Mean Rank	Chi-square	df	p	Cramer's V
Judging evidence to be more or less important	Doctoral	30	136.77	.077	2	.962	.047
	Masters	230	134.37				
	Bachelors	8	129.81				
	Total	268					
Interrogating, cross-examining	Doctoral	30	150.53	1.716	2	.424	.092
	Masters	231	133.34				
	Bachelors	8	124.63				
	Total	269					
Thinking creatively	Doctoral	30	126.88	1.325	2	.516	.136
	Masters	232	135.85				
	Bachelors	8	157.63				
	Total	270					
Motivating others	Doctoral	30	145.75	.784	2	.676	.161
	Masters	231	133.87				
	Bachelors	8	127.19				
	Total	269					
Managing others	Doctoral	30	132.20	1.306	2	.520	.149
	Masters	230	135.78				
	Bachelors	8	106.19				
	Total	268					
Using higher cognitive thinking	Doctoral	30	123.17	2.672	2	.263	.093
	Masters	229	136.48				
	Bachelors	8	103.69				
	Total	267					
Reading	Doctoral	30	137.37	.780	2	.677	.092
	Masters	231	133.93				
	Bachelors	8	156.94				
	Total	269					
Communicating verbally	Doctoral	30	123.98	1.297	2	.523	.106
	Masters	231	135.17				
	Bachelors	7	157.43				
	Total	268					
Exploring ethical issues impacting a solution	Doctoral	29	135.14	1.203	2	.548	.085
	Masters	227	133.03				
	Bachelors	8	107.88				
	Total	264					
Interpreting data on a table or graph	Doctoral	30	144.95	.802	2	.670	.115
	Masters	230	133.40				
	Bachelors	8	126.81				
	Total	268					
Exercising reflective reasoning	Doctoral	30	146.75	3.201	2	.202	.167
	Masters	232	135.30				
	Bachelors	8	99.00				
	Total	270					

Variables	Ranks			Kruskal - Wallis			Effect size
	Highest degree	N	Mean Rank	Chi-square	df	p	Cramer's V
Reasoning intuitively	Doctoral	30	123.75	.945	2	.624	.066
	Masters	229	135.69				
	Bachelors	8	124.13				
	Total	267					
Performing routine procedures	Doctoral	30	120.90	1.725	2	.422	.105
	Masters	230	136.92				
	Bachelors	8	116.06				
	Total	268					
Conducting research in a discipline	Doctoral	30	157.17	3.524	2	.172	.116
	Masters	230	131.94				
	Bachelors	8	123.13				
	Total	268					
Implementing a plan	Doctoral	30	118.77	2.823	2	.244	.139
	Masters	229	136.88				
	Bachelors	8	108.75				
	Total	267					
Thinking about thinking	Doctoral	29	135.83	.398	2	.820	.091
	Masters	231	134.87				
	Bachelors	8	118.88				
	Total	268					
Recognizing cues	Doctoral	30	125.05	.696	2	.706	.133
	Masters	231	136.32				
	Bachelors	8	134.13				
	Total	269					
Judging the credibility of a source	Doctoral	30	156.52	3.532	2	.171	.114
	Masters	231	132.52				
	Bachelors	8	125.81				
	Total	269					
Adapting protocols based on analysis of a situation	Doctoral	30	126.90	3.431	2	.180	.098
	Masters	229	136.34				
	Bachelors	8	93.50				
	Total	267					
Reasoning to make decisions, diagnose problems, project outcomes	Doctoral	30	129.57	4.399	2	.111	.098
	Masters	232	137.90				
	Bachelors	8	88.25				
	Total	270					
Growing sense of responsibility for patient outcomes	Doctoral	30	132.77	.221	2	.896	.051
	Masters	230	134.33				
	Bachelors	8	145.94				
	Total	268					

Table 5: Chi square analysis - Utilization of teaching strategies by program level

Variables	Ranks			Kruskal - Wallis			Effect size
	Program level	**N**	**Mean Rank**	**Chi-square**	**df**	**p**	**Cramer's V**
Socratic questioning	Certificate/diploma	70	99.84	6.763	2	.034	.271
	Associate degree	125	112.59				
	Bachelors degree	27	136.67				
	Total	222					
On-line discussions	Certificate/diploma	84	90.51	40.824	2	.000	.444
	Associate degree	145	149.18				
	Bachelors degree	33	158.14				
	Total	262					
In class discussions	Certificate/diploma	84	133.71	1.155	2	.561	.222
	Associate degree	147	134.69				
	Bachelors degree	33	119.67				
	Total	264					
Traditional lectures	Certificate/diploma	83	141.27	1.772	2	.412	.169
	Associate degree	148	128.01				
	Bachelors degree	33	130.59				
	Total	264					
Clinical case studies	Certificate/diploma	85	140.69	1.729	2	.421	.189
	Associate degree	146	127.82				
	Bachelors degree	32	127.97				
	Total	263					
Reflective journaling	Certificate/diploma	84	115.49	5.158	2	.076	.346
	Associate degree	143	135.89				
	Bachelors degree	32	141.78				
	Total	259					
Concept mapping	Certificate/diploma	80	119.82	.946	2	.623	.192
	Associate degree	141	128.63				
	Bachelors degree	30	130.10				
	Total	251					
High order multiple choice test items	Certificate/diploma	82	127.82	.319	2	.852	.196
	Associate degree	146	132.74				
	Bachelors degree	32	127.16				
	Total	260					

Variables	Ranks			Kruskal - Wallis			Effect size
	Program level	N	Mean Rank	Chi-square	df	p	Cramer's V
Situational judgment test items	Certificate/diploma	85	135.22	2.127	2	.345	.205
	Associate degree	148	136.49				
	Bachelors degree	33	115.65				
	Total	266					
Role playing	Certificate/diploma	84	133.13	5.479	2	.065	.190
	Associate degree	149	139.83				
	Bachelors degree	33	105.89				
	Total	266					
Case based learning	Certificate/diploma	84	130.80	.903	2	.637	.186
	Associate degree	144	133.62				
	Bachelors degree	33	120.09				
	Total	261					
Problem based learning	Certificate/diploma	85	137.41	4.611	2	.100	.223
	Associate degree	148	136.23				
	Bachelors degree	32	106.34				
	Total	265					
Collaborative learning	Certificate/diploma	84	139.39	2.954	2	.228	.146
	Associate degree	145	131.09				
	Bachelors degree	33	113.21				
	Total	262					
Portfolios	Certificate/diploma	83	118.71	1.987	2	.370	.220
	Associate degree	138	128.80				
	Bachelors degree	31	137.11				
	Total	252					

Table 6: Chi square analysis - Utilization of teaching strategies by highest degree

Variables	Ranks			Kruskal - Wallis			Effect size
	Highest degree	**N**	**Mean Rank**	**Chi-square**	**df**	**p**	**Cramer's V**
Socratic questioning	Doctoral	27	113.63	2.199	2	.333	.217
	Masters	188	112.48				
	Bachelors	7	76.86				
	Total	222					
On-line discussions	Doctoral	30	164.12	7.989	2	.018	.242
	Masters	224	128.16				
	Bachelors	8	102.75				
	Total	262					
In class discussions	Doctoral	29	132.31	3.268	2	.195	.188
	Masters	226	133.59				
	Bachelors	8	85.88				
	Total	263					
Traditional lectures	Doctoral	30	118.82	1.893	2	.388	.163
	Masters	225	134.50				
	Bachelors	8	111.25				
	Total	263					
Clinical case studies	Doctoral	29	145.41	3.866	2	.145	.253
	Masters	225	131.27				
	Bachelors	8	87.56				
	Total	262					
Reflective journaling	Doctoral	28	143.79	1.203	2	.548	.181
	Masters	223	128.57				
	Bachelors	8	121.75				
	Total	259					
Concept mapping	Doctoral	27	138.89	1.516	2	.469	.185
	Masters	217	125.01				
	Bachelors	7	106.86				
	Total	251					
High order multiple choice test items	Doctoral	29	126.28	.133	2	.936	.188
	Masters	223	130.90				
	Bachelors	8	134.75				
	Total	260					
Situational judgment test items	Doctoral	30	131.12	.157	2	.925	.221
	Masters	227	133.58				
	Bachelors	8	123.63				
	Total	265					
Role playing	Doctoral	30	133.83	.084	2	.959	.225
	Masters	227	132.63				
	Bachelors	8	140.25				
	Total	265					
Case based learning	Doctoral	29	136.29	2.178	2	.337	.189
	Masters	224	131.64				
	Bachelors	8	94.00				
	Total	261					

Variables	Ranks			Kruskal - Wallis			Effect size
	Highest degree	N	Mean Rank	Chi-square	df	p	Cramer's V
Problem based learning	Doctoral	30	140.12	1.521	2	.467	.186
	Masters	226	132.52				
	Bachelors	8	103.44				
	Total	264					
Collaborative learning	Doctoral	30	131.63	2.693	2	.260	.175
	Masters	223	132.43				
	Bachelors	8	88.75				
	Total	261					
Portfolios	Doctoral	28	136.70	.727	2	.695	.221
	Masters	217	125.10				
	Bachelors	7	129.14				
	Total	252					

Table 7: Chi square analysis - Utilization of assessment measures by program level

Variables		Ranks		Kruskal-Wallis			Effect size
	Program level	**N**	**Mean Rank**	**Chi-Square**	**df**	**p**	**Cramer's V**
Course exam results	Certificate/diploma	85	139.47	.858	2	.651	.056
	Associate degree	155	138.64				
	Bachelors degree	34	127.38				
	Total	274					
ARRT exam results	Certificate/diploma	85	147.98	4.017	2	.134	.121
	Associate degree	155	135.29				
	Bachelors degree	34	121.38				
	Total	274					
Clinical competency results	Certificate/diploma	85	145.16	3.774	2	.152	.118
	Associate degree	155	136.22				
	Bachelors degree	34	124.21				
	Total	274					
Image critique performance	Certificate/diploma	85	147.43	3.648	2	.161	.116
	Associate degree	155	135.00				
	Bachelors degree	34	124.06				
	Total	274					
Specific course assignments	Certificate/diploma	85	147.87	3.554	2	.169	.114
	Associate degree	155	134.66				
	Bachelors degree	34	124.50				
	Total	274					
Situational judgment test items	Certificate/diploma	85	144.96	1.789	2	.409	.081
	Associate degree	155	134.77				
	Bachelors degree	34	131.26				
	Total	274					
Portfolios	Certificate/diploma	85	138.84	.135	2	.935	.022
	Associate degree	155	137.18				
	Bachelors degree	34	135.62				
	Total	274					
Reflective Journals	Certificate/diploma	85	136.23	.308	2	.857	.034
	Associate degree	155	138.83				
	Bachelors degree	34	134.62				
	Total	274					
Clinical case study performance	Certificate/diploma	85	132.63	1.316	2	.518	.069
	Associate degree	155	137.88				
	Bachelors degree	34	147.94				
	Total	274					

Variables		Ranks		Kruskal-Wallis			Effect size
	Program level	**N**	**Mean Rank**	**Chi-Square**	**df**	**p**	**Cramer's V**
Employer surveys	Certificate/diploma	85	150.38	6.268	2	.044	.152
	Associate degree	155	134.15				
	Bachelors degree	34	120.56				
	Total	274					
Student surveys	Certificate/diploma	85	147.42	3.603	2	.163	.115
	Associate degree	155	135.36				
	Bachelors degree	34	122.44				
	Total	274					
Standardized test (such as the WGCTA or CCTST)	Certificate/diploma	85	137.22	.035	2	.983	.011
	Associate degree	155	137.54				
	Bachelors degree	34	138.03				
	Total	274					

Table 8: Chi square analysis - Utilization of assessment measures by highest degree

Variables		Ranks		Kruskal - Wallis			Effect size
	Program level	**N**	**Mean Rank**	**Chi-Square**	**df**	**p**	**Cramer's V**
Course exam results	Doctoral	30	138.70	1.008	2	.604	.061
	Masters	235	135.99				
	Bachelors	8	160.31				
	Total	273					
ARRT exam results	Doctoral	30	128.65	1.035	2	.596	.062
	Masters	235	138.62				
	Bachelors	8	120.69				
	Total	273					
Clinical competency results	Doctoral	30	127.60	1.195	2	.550	.066
	Masters	235	138.44				
	Bachelors	8	129.88				
	Total	273					
Image critique performance	Doctoral	30	119.80	2.581	2	.275	.097
	Masters	235	138.77				
	Bachelors	8	149.38				
	Total	273					
Specific course assignments	Doctoral	30	160.15	4.213	2	.122	.124
	Masters	235	134.50				
	Bachelors	8	123.75				
	Total	273					
Situational judgment test items	Doctoral	30	135.95	.142	2	.931	.023
	Masters	235	137.40				
	Bachelors	8	129.13				
	Total	273					
Portfolios	Doctoral	30	136.70	.919	2	.632	.058
	Masters	235	136.51				
	Bachelors	8	152.63				
	Total	273					
Reflective Journals	Doctoral	30	145.30	2.229	2	.328	.091
	Masters	235	136.59				
	Bachelors	8	118.00				
	Total	273					

Variables		Ranks		Kruskal - Wallis			Effect size
	Program level	**N**	**Mean Rank**	**Chi-Square**	**df**	**p**	**Cramer's V**
Clinical case study performance	Doctoral	30	137.55	4.679	2	.096	.131
	Masters	235	138.61				
	Bachelors	8	87.50				
	Total	273					
Employer surveys	Doctoral	30	112.75	5.062	2	.080	.136
	Masters	235	140.34				
	Bachelors	8	129.81				
	Total	273					
Student surveys	Doctoral	30	121.65	2.847	2	.241	.102
	Masters	235	139.75				
	Bachelors	8	113.69				
	Total	273					
Standardized test (such as the WGCTA or CCTST)	Doctoral	30	134.00	.988	2	.610	.060
	Masters	235	137.49				
	Bachelors	8	134.00				
	Total	273					

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