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Examining the Effectiveness of an Educational Intervention Aimed at Teaching Critical Thinking to Radiography Students: a Mixed Methods Approach

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EXAMINING THE EFFECTIVENESS OF AN EDUCATIONAL INTERVENTION AIMED AT TEACHING CRITICAL THINKING TO RADIOGRAPHY STUDENTS: A MIXED METHODS APPROACH

by

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Life is a journey. Each day brings an unfamiliar road in which to travel. Over the course of my life, I have taken some correct and incorrect turns. Though not enjoyable when faced with these “incorrect turn” circumstances, the incorrect turns have fostered my faith, built resiliency, and molded my character. I would likely not be where I am today without having faced the rocky roads. The unconditional love and support from my family and friends has enable me to maneuver through the rocky roads, and for that, I am forever grateful. My accomplishments have not been achieved in isolation. I am indebted to the formative guidance offered by my PhD committee who made this journey manageable. My sincerest appreciation to you all! I am guided each and every moment by something greater than me alone. It is through my faith in God that I have persevered through this journey. Lastly, and most importantly, this thing called life would be unfilled and uninspired if not for my two boys, Ian and Noah. They have chartered this journey with me. They are my continued inspiration and reason for not giving up. Look boys, if mom can do it, so can you! Set a goal and be prepared to work hard to accomplish it. The journey will not be easy, and you will likely make some incorrect turns along the way. But no matter what, I will be your biggest cheerleader. You have my forever, unconditional love!

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University of Nebraska, 2018

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Critical thinking affords future healthcare practitioners with the cognitive skills and affective dispositions needed in a continuously evolving workforce. The need for critical thinking in healthcare practice is evident and well-established; however, the deliberate teaching of critical thinking in educational programs remains an area for growth. This dissertation research investigated the effectiveness of an educational intervention designed to progress critical thinking in radiography students through a mixed methods approach. An intervention mixed methods design with components of convergent and explanatory features enabled the research questions to be investigated. Changes in test scores generated from the California Critical Thinking Skills Test and reflections found in journal entries and a post-intervention survey served as the quantitative and qualitative data sets. The merging of the quantitative and qualitative data sets provided a rich understanding of how the educational intervention progressed critical thinking among the radiography students. The key findings from this research suggested that there was no significant difference between changes in test scores between the experimental and control groups; however, the experimental group felt the educational intervention positively changed their critical thinking behaviors. The results generated from the dissertation will advance the imaging science field by providing evidence where there are gaps in knowledge.

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INTRODUCTION

Administering harmful ionizing radiation, adjusting equipment parameters, assessing patient pathologies and physical motility, producing quality images with minimal error, and analyzing orders to validate congruency with presented patient conditions are just a few of the day-to-day responsibilities of a radiologic technologist. How well can a radiologic technologist carry out these responsibilities without critical thinking? Patients rely on radiologic technologists, or imaging science professionals, to possess the cognitive thought processes and affective dispositions to provide quality care and service, especially in terms of patient safety given the physics behind image production. Without critical thinking, the radiologic technologist becomes armed with a deadly weapon; ionizing radiation. Critical thinking is a professional standard and patient expectation. How is academia preparing future radiologic technologists to be critical thinkers?

The human aptitude to respond to the demands constantly arising in the modern world is a need concerning all parts of the universe. These demands for higher-order thinking follow not only the acceleration of the pace of change but also the intensification of complexity and interdependence, thus resulting in the need for critical thinking to be a central mission in education (Anastasiadou & Dimitriadou, 2011; Assaf, 2009; Frangoudaki, 2004; Hamers & Overtoom, 1999). Health science education is not immune to this universal need. The pressure for healthcare professionals to be able to effectively evaluate unique patient conditions in real-world scenarios is ever-present. Consequently, there is a need for educators to provide the framework and educational strategies to foster the progression of critical thinking in students so they enter the workforce equipped with the framework, skill set, and self-efficacy to employ best practices. These future practitioners are critical thinkers able to strategize through the complex challenges they face on a daily basis.

Given the changing demands from the modern world and heightened expectations of healthcare services and care rendered to patients, the demand for educational reform to strengthen the learning infrastructure to support the progression of critical thinking is essential (Carr, 2015; Hung, Tang, & Ko, 2015). The problem is while academic institutions are fully aware of the need for critical thinking development, educators are often unfamiliar with the instructional activities best suited to facilitate critical thinking. Are there specific academic activities that promote the development of critical thinking? Existing literature suggests there are educational activities able to teach critical thinking. However, opportunities remain to explore those learning strategies to determine their effectiveness in promoting critical thinking behaviors in future imaging science professionals.

Purpose of the Research Study

The purpose of the research study was to determine the effectiveness of an educational intervention aimed at teaching critical thinking to radiography students. The educational intervention introduced the Paul-Elder critical thinking framework through an e-learning module followed by a reflective journaling exercise designed to facilitate the application of the framework after clinical experiences typically associated with critical thinking opportunities. The study aimed to determine whether or not the intervention was effective by calculating changes in test scores from a critical thinking assessment tool and examining qualitative reflections from journals and a post-intervention survey. The findings generated from the research will guide educators when seeking to deliberately teach critical thinking.

Statement of the Problem

Vast literature related to educational strategies used to teach critical thinking exists; however, there remains an ever-present gap regarding the effectiveness of these strategies in the field of imaging science. Can imaging science students be taught critical thinking by introducing them to a framework which is reinforced through reflective journaling? Do critical thinking test scores change following the educational intervention aimed at teaching critical thinking? What are the students' reflections, perceptions, and experiences as they relate to critical thinking and the intervention? The quantitative and qualitative data generated from the research would advance the profession and begin to fill gaps present in the literature.

Research Questions

The following research questions guided the study:

Guiding Questions: Is there an educational intervention that can effectively teach critical thinking to imaging science students? What does the literature suggest as a productive learning strategy to teach critical thinking, and is it applicable to the imaging science profession? What does the literature suggest as an evidence-supported thinking framework or model, and is it applicable to the imaging science profession?

Research Question One (Quantitative): Was the chosen educational intervention proven effective as determined by comparing changes in scores on a critical thinking assessment tool between the experimental and control groups?

Research Question Two (Qualitative): How did the qualitative data generated from the journaling and the participants' post-intervention reflections enhance the overall understanding of the intervention's effectiveness in teaching critical thinking?

Research Question Three (Mixed Methods Integration): What conclusions can be made regarding the effectiveness of the intervention when the two data sets, quantitative and qualitative, merge together?

Significance of the Research Study

With the ever-present need for curricular reform to align with the changing demands of healthcare, a proven educational strategy aimed to effectively teach critical thinking is invaluable. Educators may acknowledge the need for reform but lack the groundwork for how to effectively teach the desired outcome. An evidence-supported educational strategy can drive academia forward, particularly in a discipline where the literature is scarce. There is literature related to the definition of critical thinking, critical thinking frameworks, and even the instructional activities that best foster critical thinking; however, very limited research has been conducted on how the frameworks and supporting learning exercises apply to the field of imaging science. This pilot research aims to investigate an educational strategy used to promote the development of critical thinking in radiography students. The findings generated from the pilot study can be modified, enhanced, and tailored to a more expansive research effort. Ultimately, the results of this pilot study will serve as a foundation for future scholarship and hold significant contributions to a field where science is deficient.

The importance of this research is further validated by professional organizations, credentialing bodies, and programmatic accreditors who place strong emphasis on critical thinking behaviors. According to the American Registry of Radiologic Technologists (ARRT)'s Code of Ethics (2017), "The radiologic technologist assesses situations; exercises care, discretion, and judgment; assumes responsibility for professional decisions; and acts in the best interest of the patient" (p.1). The American Society of Radiologic Technologists (ASRT) promotes Practice Standards within the profession. Within these ASRT Practice Standards (2016), it states, “Radiographers think critically and use independent, professional and ethical judgments in all aspects of their work” (p.R3). Moreover, the Joint Review Committee on Education in Radiologic Technology (JRCERT), an accrediting body for education in imaging science, requires programs to provide outcomes validating that the student has demonstrated critical thinking skills (2014).

There are many stakeholders invested in future imaging science professionals who demonstrate critical thinking behaviors: educators, professional organizations, credentialing bodies, programmatic accreditors, healthcare industry, and patients. Patients rely on imaging science professionals to demonstrate best practices. How these professionals administer and handle ionizing radiation, set exposure parameters, make protocols adjustments – all greatly influence the quality of care the patient receives. Are imaging science professionals causing unnecessary harm or preventing it? Educators have a responsibility to equip students transitioning into practice with the framework for critical thinking so that as non-textbook situations arise and the scope of healthcare changes, they are armed with the skill set and knowledge-base for success. The scaffolding for success starts in academia with an evidence-supported educational strategy in hand. Without an effective strategy, educators remain in question as to how the desired outcome can be reached.

CHAPTER 1: LITERATURE REVIEW

Defining Critical Thinking

A review of the literature generated a multitude of definitions for critical thinking due to its abstract nature, even though, some common threads are evident. The literature suggested that the inception of the critical thinking movement began with the work of Socrates who drove the methodology of asking questions, probing for answers, and challenging the beliefs of authority. Socrates searched for the essence of reason and truth which encouraged the exploration of theories, evidence, assumptions, and implications. The movement arising from Socrates' search for the truth influenced the writing of future theorists who in turn shaped the definition and educational implications surrounding the construct of critical thinking (Paul, Elder, & Bartell, 1997). Watson and Glaser, Paul and Elder, Brookfield, and Ennis are prominent theorists that have provided definitions of critical thinking used heavily across disciplines.

Watson and Glaser (1964) describe critical thinking as a construct comprised of knowledge, attitude, and skill. Knowledge denotes the process of making logical conclusions from accurate inferences, abstractions, and general knowledge. Attitude refers to the disposition to acknowledge problems, willingness to seek out the facts or evidence, and fortitude to work toward revealing the truth. Skill is associated with the capacity to apply knowledge and attitude (Watson & Glaser, 1964).

Paul and Elder (2004) offer a definition most applicable when assessing critical thinking abilities. The researchers suggest that critical thinking is the process of analyzing and assessing thinking with the aim to improve it. The analysis of thinking requires knowledge of the elements of thought. The assessment of thinking about any subject or content hinges on knowledge of the standards of thought. Critical thinking is an intellectual process of synthesizing and evaluating information collected from experiences, reflection, and reasoning. The researchers summarize critical thinking as the ability to engage in purposeful thought without influence of biases. Paul indicates that metacognition, or thinking about thinking, resides at the core of critical thinking. Critical thinkers self-regulate their own thought processes in an effort to improve (Colucciello, 1997).

Brookfield (1987) views critical thinking as a process; a process of identifying and challenging assumptions, challenging the importance of context, acknowledging and investigating alternatives, and demonstrating reflective skepticism. The premise of reflective skepticism suggests the act of constantly questioning the status quo. Critical thinking sets to answer the unknown by exploring various alternatives.

The work of Ennis (1985) describes critical thinking as deciding what to believe or do based upon reflective and reasonable thinking. Like Paul and Elder, Ennis suggests that a critical thinker remains cognizant of his/her own assessment of thinking. Making judgments and decisions only after exploring a number of alternatives serves as the foundation of Ennis' interpretation of critical thinking. It is implied that decisions not be rushed to a conclusion; rather, to suspend a final judgment until deliberate effort to examine all assumptions, theories, generalizations, and hypotheses is concluded.

Critical thinking involves dimensions of both cognitive skills and affective dispositions as proposed by a panel of experts. The Delphi consensus project executed through a collaboration of scholars from a variety of disciplines developed a definition of critical thinking in unity, which forms the foundation of this research study.

The Delphi definition stated the following:

> Critical thinking is purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological considerations upon which that judgment is based. …. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, prudent in making judgments, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. (Facione, 1990, p. 3)

The Delphi consensus project aimed to provide guidance for educational assessment and instruction as it relates to the construct of critical thinking. Leaders in the critical thinking movement advocated for curricular reform that included effective and meaningful pedagogy, assessment, and learning strategies to facilitate the cognitive skills and inquiry associated with critical thinking (Facione, 1990). The movement gained momentum when universities and state departments of education introduced critical thinking standards and frameworks. The consensus definition generated as a result of the project's efforts served as a guide for the educational standards and frameworks in demand at the time of the movement. The definition, rooted in cognitive skills and affective dispositions, builds the conceptualization of critical thinking which continues to evolve curricular reform today.

Early research in the field of critical thinking acknowledged the difference between the *ability* to think critically versus the *disposition* to do so (Ennis, 1985). Since Ennis' work, there has been a large body of research to further support the notion of a significant correlation between critical thinking dispositions and ability (Colucciello, 1997;

Dwyer, 2011; Facione, 2000; Facione, Sanchez, & Facione, 1994; Profeto-McGrath, 2003; Rimiene, 2002).

Cognitive skills of critical thinking include interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 1990). Some literature would also indicate deductive and inductive reasoning to be aligned with the cognitive skills dimension (Paul, 1995). Arising from these core cognitive skills, sub-skills can be associated with the cognitive dimension of critical thinking. See Table 1 below for a breakdown of the associated descriptors and sub-skills.

Table 1

Cognitive Skills of Critical Thinkers (adapted from Facione, 1990; Paul, 1995)

Dimension	Description	Associated Sub-skills
Interpretation	Comprehending or expressing the meaning behind a wide variety of experiences, situations, judgments, rules, or procedures.	Categorization Decoding Significance Clarifying Meaning
Analysis	Identifying the intended or actual inferential relationships among statements, or questions intended to express beliefs, judgments, experiences or opinions.	Examining Ideas Identifying Arguments Analyzing Arguments
Evaluation	Assessing the creditability of statements which are accounts of a person's perception, experience, situation, judgment, belief, or opinion; assessing the logical strength of relationships.	Assessing Claims Assessing Arguments
Inference	Identifying and securing elements needed to draw reasonable conclusions; considering relevant information and determining the consequences from data, evidence, and judgments.	Querying Evidence Conjecturing Alternatives Drawing Conclusions
Explanation	Stating the results of one's reasoning; justifying that reasoning in terms of the evidential, conceptual, and contextual considerations; presenting one's reasoning in the form of cogent arguments.	Stating Results Justifying Procedures Presenting Arguments
Self-Regulation	Self-consciously monitoring one's cognitive activities, the elements used in those activities, and the results educed, or correcting one's reasoning.	Self-examination Self-correction
Inductive Reasoning	An argument's conclusion is purportedly warranted but not necessitated by the assumed truth of its premises.	
Deductive Reasoning	The assumed truth of the set of premises purportedly necessitates the truth of conclusion.	

While cognitive skills and circumstances impact the ability of someone to think critically, ultimately some people think critically in a situation while others do not. If an individual has the requisite skills and knowledge to think critically but does not, and a circumstantial influence cannot be found, it stands to reason that there is a dispositional driver for critical thinking (Willis, 2004). This phenomenon drove researchers to examine the dispositions behind why some people with the cognitive skills and abilities decide to engage in critical thinking while others do not. Researchers were looking for the "critical spirit", that way of living which is symbolic of critical thinking (Facione, 1998).

The affective dispositions, as proposed by Facione (2000), is the terminology used to reference the characterological attributes of individuals. With that, a disposition is "an individual's consistent internal motivation to act toward or to respond to, persons, events, or circumstances in habitual, and yet potentially malleable ways" (p. 64). John Dewey (1933) was a pioneer in describing the significance of these habits of the mind…"If we were compelled to make a choice between these personal attributes and knowledge about the principles of logical reasoning together with some degree of technical skill in manipulating special logical processes, we should decide for the former" (p.34). The disposition towards critical thinking results from a habit of the mind to engage in problems and make decisions using the cognitive skills and abilities suggestive of critical thinking (P. Facione, Facione, & Giancarlo, 1996).

Work from Facione et al. (1994) generated a list of the dispositions associated with critical thinking. Affective dispositions found to be linked with critical thinking include: inquisitiveness, open-mindedness, systematicity, analyticity, truth-seeking, self-confidence, and maturity. Many of these attributes can be found in the Delphi consensus definition. See Table 2 below for a description of each disposition.

Table 2

Descriptions of the Affective Dispositions Associated with Critical Thinking (adapted from Facione et al., 1994)

Dispositions	**Description**
Inquisitiveness	One's intellectual curiosity and desire for learning even when the application of the knowledge is not readily apparent
Open-mindedness	Being tolerant of divergent views and sensitive to the possibility of one's own bias
Systematicity	Being organized, orderly, focused, and diligent in inquiry
Analyticity	Prizing the application of reasoning and the use of evidence to resolve problems, anticipating potential conceptual or practical difficulties, and consistently being alert to the need to intervene
Truth-Seeking	Being eager to seek the best knowledge in a given context, courageous about asking questions, and honest and objective about pursuing inquiry even if the findings do not support one's self-interests or one's preconceived opinions
Self-Confidence	To trust the soundness of one's own reasoned judgments and to lead others in the rational resolution of problems
Maturity	Approaches problems, inquiry, and decision making with a sense that some problems are necessarily ill-structured, some situations admit of more than one plausible option and many times judgments must be made based on standards, contexts and evidence which preclude certainty

Literature has also suggested that the disposition toward critical thinking, as identified by the seven descriptors above, is significantly related to ego-resiliency. According to Block and Block (1980), ego-resiliency refers to an individual's ability to alter his/her modal perceptual and behavioral functioning to adapt to situational constraints and challenges. Ego-resiliency implies the person is flexible, resourceful, and adaptable. Additionally, literature has suggested a strong correlation between motivation and critical thinking. Motivation serves to activate the cognitive and metacognitive resources necessary for good critical thinking behaviors (Ennis, 1996; Norris, 1994; Perkins, Jay, & Tishman, 1993).

The precise interworking of how skills and dispositions correlate to one another in the execution of critical thinking remains an area for future research. Some researchers argue that an individual must first possess a critical thinking disposition before applying the skills. Others theorize that when a person attempts to utilize critical thinking skills and finds success, this success reinforces one's disposition toward critical thinking. Another theory suggests the possibility of a dependent relationship between specific combinations of dispositional attributes and sets of critical thinking skills. For example, open-mindedness may propel an individual to ask analytical questions or to investigate alternatives (P. Facione, Sanchez, Facione, & Gainen, 1995). Until empirical research exists to prove or disprove the theories, educators are left to emphasize both cognitive skills and dispositional attributes in curricular design.

Critical Thinking Framework

Frameworks are developed to address educational objectives and guide instructional design and cognitive development toward the construct at hand (Dwyer, Hogan, & Stewart, 2014). A critical thinking framework serves to put dispositions and cognitive skills into action. An effective framework is a scaffold for the learner to practice and exhibit key attributes and behaviors. Applying a chosen framework to a given situation can move the learner toward critical thinking (Duron, Limbach, & Waugh, 2006). Just as literature offers an array of operational definitions for the construct of critical thinking, so are there varying frameworks to facilitate it.

Perhaps one of the first attempts at providing a framework for critical thinking from an educational perspective and application was from Benjamin Bloom. Bloom (1956) offered a taxonomy of instructional activities associated with varying complexity levels of the cognitive domain. On one end of the spectrum, lower-order thinking resides and on the opposite end, more complex and higher-order thinking is found. Over the years, the taxonomy has been revised, especially on the higher-order end of the spectrum as well as the manner in which instructional objectives are written (Anderson et al., 2001). A comparison of the taxonomies of the cognitive domain from the original to the revised is found in Table 3 below.

Table 3

Bloom's vs Anderson & Krathwohl's Revised Taxonomy: A Comparison (adapted from Wilson, 2017)

Bloom's Taxonomy 1956	**Anderson and Krathwohl's Taxonomy 2001**
1. Knowledge: Remembering or retrieving previously learned material. Examples of verbs that relate to this function are: relate, list, memorize	1. Remembering: Recognizing or recalling knowledge from memory.
2. Comprehension: The ability to grasp or construct meaning from material. Examples of verbs that relate to this function are: locate, explain, identify	2. Understanding: Constructing meaning from different types of functions be they written or graphic messages or activities like interpreting, exemplifying, classifying, summarizing, inferring, comparing, or explaining.
3. Application: The ability to use learned material, or to implement material in new and concrete situations. Examples of verbs that relate to this function are: apply, develop, interpret	3. Applying: Carrying out or using a procedure through executing, or implementing.
4. Analysis: The ability to break down or distinguish the parts of material into its components so that its organizational structure may be better understood. Examples of verbs that relate to this function are: analyze, compare, investigate	4. Analyzing: Breaking materials or concepts into parts, determining how the parts relate to one another or how they interrelate, or how the parts relate to an overall structure or purpose.
5. Synthesis: The ability to put parts together to form a coherent or unique new whole. Examples of verbs that relate to this function are: produce, create, invent	5. Evaluating: Making judgments based on criteria and standards through checking and critiquing.
6. Evaluation: The ability to judge, check, and even critique the value of material for a given purpose. Examples of verbs that relate to this function are: judge, measure, evaluate	6. Creating: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.

The framework by Anderson et al. (2001) placed knowledge as a separate dimension with metacognitive knowledge being a unique extension. Metacognitive knowledge refers to the strategic knowledge, knowledge about cognitive processes and functions, and ultimately self-knowledge.

This notion of metacognitive knowledge is additionally supported by the taxonomy suggested by Marzano (2001). In this taxonomy, the metacognitive system acts as the executive control system concentrated on goal and process specification and disposition monitoring (Marzano, 1998). Similar to the taxonomies described above, Marzano's framework includes a knowledge or cognitive domain and processes of knowledge retrieval (i.e. memory, recall), comprehension (i.e. knowledge representation), analysis (i.e. generalizing, identifying errors), and knowledge utilization (i.e. decision-making, investigation). At the peak of the taxonomy hierarchy, the self-system in which goals are generated resides. The self-system guides whether or not a given task will be undertaken as guided by motivation, attention, and beliefs (Dwyer et al., 2014).

The aforementioned taxonomies offer insight to the key thinking processes and the associations between them; however, these taxonomies can leave a deficiency in terms of how the processes can be applied to a given situation (Krathwohl, 2002; Moseley et al., 2005). This need for application is provided by various critical thinking frameworks offered by a number of researchers in the fields of academia and social sciences.

A framework for critical thinking aimed to identify explicit learning outcomes is provided by the work of Dwyer et al. (2014). These researchers argue that an integrated framework is the best approach to teaching critical thinking. The integration of reflective judgment and self-regulatory functions of metacognition which both influence the execution of thinking processes (i.e. analysis, evaluation and inference) is the premise of the framework. In this framework, researchers argue that reflective judgment aligns with the dispositional aspect of critical thinking more heavily than the ability and skills dimension. The integrated framework emphasizes that learning is impacted by comprehension and memory. Comprehension, or building understanding, involves explaining or summarizing information based upon connections to previously learned knowledge (Huitt, 2011). Sweller (1999) suggests that comprehension represents the ability to integrate schemas from long-term memory with new information simultaneously in working memory. When comprehension occurs, changes in long-term memory result (Sweller, 2005). See Figure 1 below for a depiction of the integrated framework.

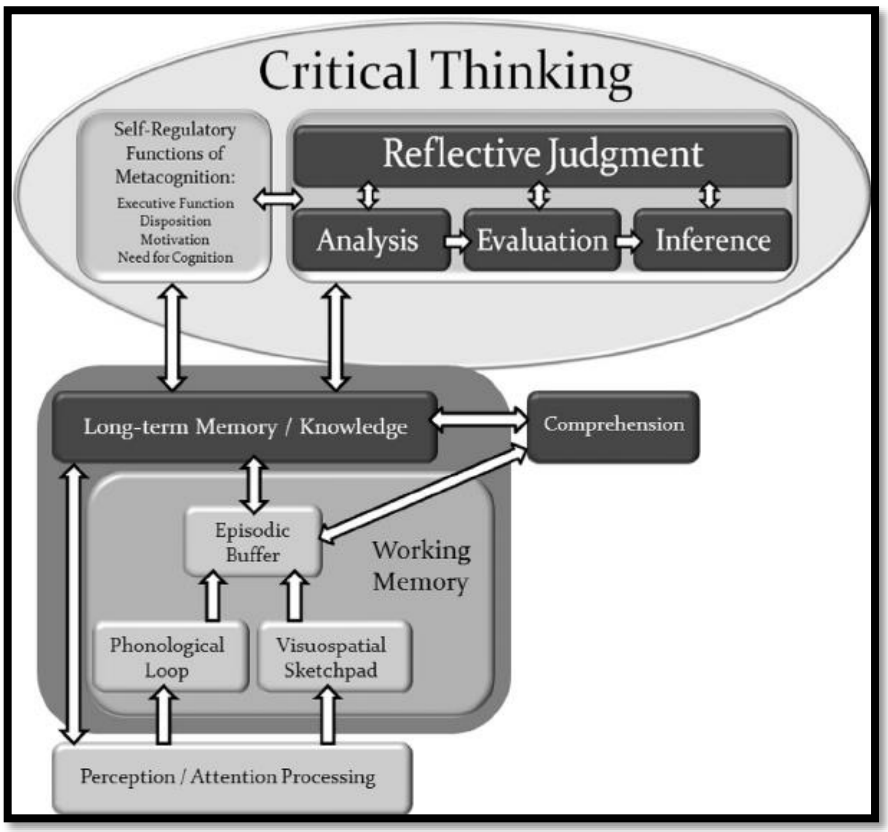

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Figure 1. An integrated critical thinking framework (Dwyer et al., 2014).

Duron et al. (2006) offer an interdisciplinary framework which aims to drive the learner toward critical thinking through existing theories and best practices in cognitive development, effective learning environments, and outcomes-based assessments. The five-step model is geared toward implementation in the educational setting.

The model starts with determining learning objectives which set to identify the key behaviors the students are expected to exhibit upon completion of the course or learning activity. To promote critical thinking, the learning objectives are tied to the higher-order thinking levels of Bloom's (1956) taxonomy. Step two of the framework is teaching through questioning. Questions serve to assess what is already known and to develop new understandings. These questions can be categorized as convergent or divergent. Convergent questions seek specific answers while divergent questions seek a variety of applicable answers. Using Bloom's, convergent questions would be associated with lower-levels such as *knowledge*, *comprehension*, and *application*. Divergent questions apply to the higher-levels of Bloom's such as *synthesis* and *evaluation*. Step three is to practice before assessing. The practice component pertains to active learning activities which encourage the learner to think about what they are doing. Step four is to review, refine, and improve. This step suggests that educators need to evaluate whether or not the chosen instructional techniques are effective in driving the learner towards critical thinking. The effectiveness can be evaluated through student feedback. The final step is to provide feedback and assessment of learning. In this step, standards are compared to student performance. The feedback sets to improve the quality of student learning. See Figure 2 below for a diagram of the 5-Step framework.

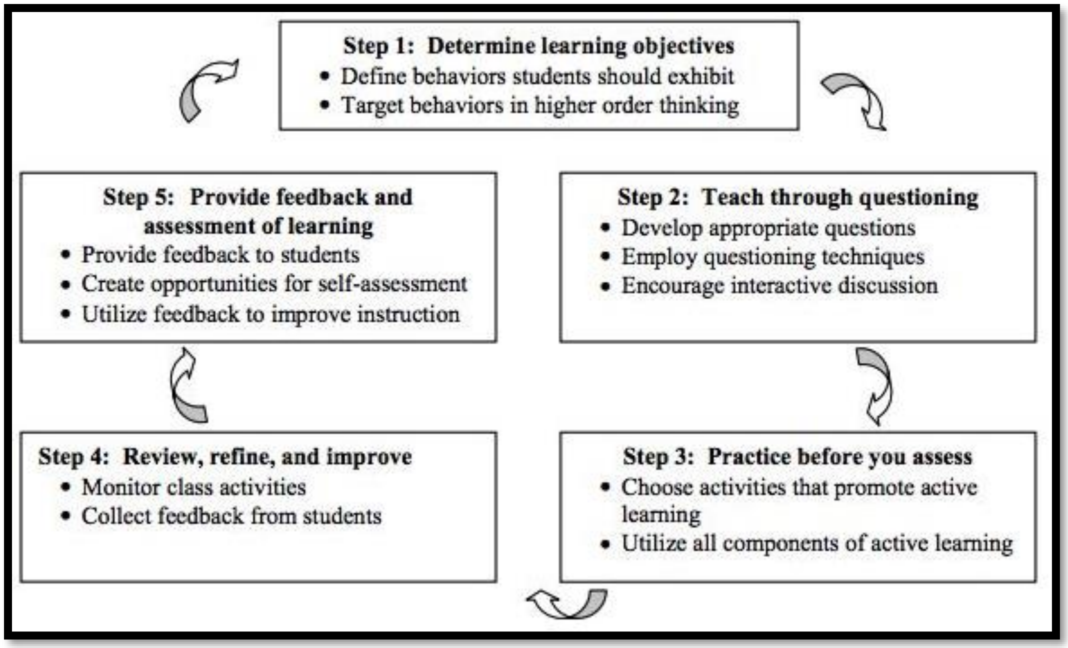


Figure 2. 5-Step model to move students toward critical thinking (Duron et al., 2006).

In addition to providing a well-established definition for critical thinking, Paul and Elder also offer a framework which has been referenced in a number of research studies (Beistle, 2012; Evans & Chen, 2010; Hohmann & Grillo, 2014; McClellan, 2016; Novotny, Stapleton, & Hardy, 2016; Ralston & Bays, 2013; Reed & Kromrey, 2001; Thompson, Ralston, & Hieb, 2012). Paul and his colleagues at the Foundation for Critical Thinking have dedicated their life's work to evolve and advance the understanding of the concept of critical thinking over the past quarter of a century. These experts argue that critical thinking is relevant to every subject, discipline and profession as well as to the day-to-day reasoning in one's life (Paul & Elder, 2006). This well-established and proven framework will serve as the theoretical foundation utilized in this dissertation study.

The Paul-Elder model hinges on the declaration that critical thinking ought to be self-directed, self-monitored, and self-correcting by thinking with humility, perseverance, integrity, and responsibility (Paul & Elder, 2006). This declaration is directly transferable to the expectations for performance and behaviors within the healthcare genre. Healthcare providers are expected to be self-directed, to think responsibly while exhibiting humility and empathy toward patients.

The foundation of the Paul-Elder framework consists of intellectual standards which are applied to elements of reasoning to develop intellectual traits. See Figure 3 below for a depiction of the framework.

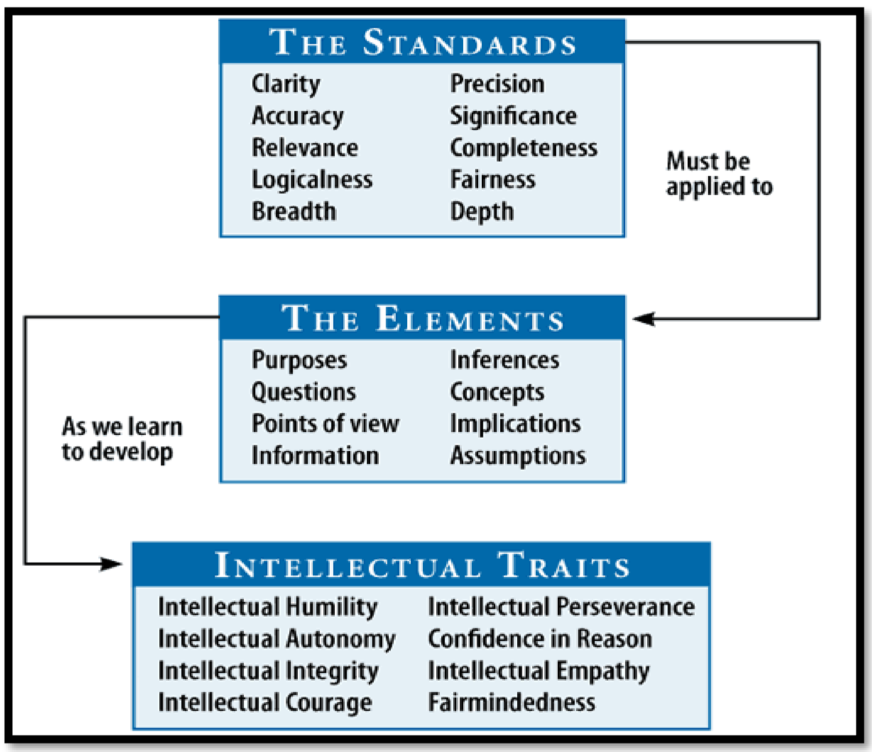


Figure 3. Paul-Elder critical thinking framework (Paul & Elder, 2006).

To understand the label of "Intellectual Standards", intellectual and standards as individual constructs can be defined followed by an examination of the meaning of the words in concert together. Standards refer to some measure, guideline, or model with which elements of the same class or categorization are compared in order to determine their quality, value, or quantity. Often times, standards are used to gauge the quality of something; ultimately leading to a determination of acceptance or rejection. As judgments are made, it is difficult to make decisions without standards or criterion in which to compare (Paul & Elder, 2013). Intellectual means requiring intellect or exhibiting a high degree of intelligence. If one possesses intellect, he/she possesses the ability to understand and perceive relationships and make comparisons. Someone with intelligence is able to learn from experiences, acquire new knowledge, and retain previously learned information. Intellectual people tend to reason through problems and make sound judgments in the pursuit of knowledge (Paul & Elder, 2013).

Taking the individual descriptions of the constructs, intellectual and standards, the framework develops a conceptualization of the words and their meanings in concert. Paul and Elder (2013) conceptualize intellectual standards as the standards necessary for generating sound decisions and for reasoning effectively, for forming knowledge (as opposed to unsound beliefs or assumptions), for intelligent understanding, and for rational and logical thinking. Intellectual standards are required for the mind's continuous assessment and awareness of the strengths and weaknesses in thinking, both personally and that of others (Paul & Elder, 2013). Applying intellectual standards to decisions and judgments is essential to functioning as fair-minded, reasonable individuals.

Critical thinkers apply standards to elements of thought. "Elements of Thought" is the phase of the framework in which the critical thinker looks for interrelationships or connections between concepts, ideas, or theories. Paul and Elder (2005) suggest that all subjects represent a systematic way of thinking defined by a system of ideas generating a distinctive and methodical way of questioning. Without learning the ideas that define and structure a body of content, learning cannot take place. For instance, to learn the identity of a radiographer is to learn how to distinguish a radiographer from a radiologist or nurse. For learning to occur, one must learn to think accurately and reasonably according to the indicators that define the content. Ideas within a content matter are uniquely connected with the kind of questions asked in it. For example, to understand what a radiographer does, one must first seek answers to questions and problems relevant to radiology practice. Radiology is studied to decipher imaging science procedures and practices (to answer questions about the field). Paul and Elder (2005) claim that all subjects can be understood in this way.

Within the framework, "Elements of Thought" represents eight basic structures present in all thinking. Whenever one thinks, he/she thinks for a purpose within a point of view based on assumptions leading to implications and consequences. Critical thinkers use ideas and theories to interpret data, facts, and experiences so that questions can be answered, problems solved, and issues resolved (Paul & Elder, 2006). See Figure 4 below.

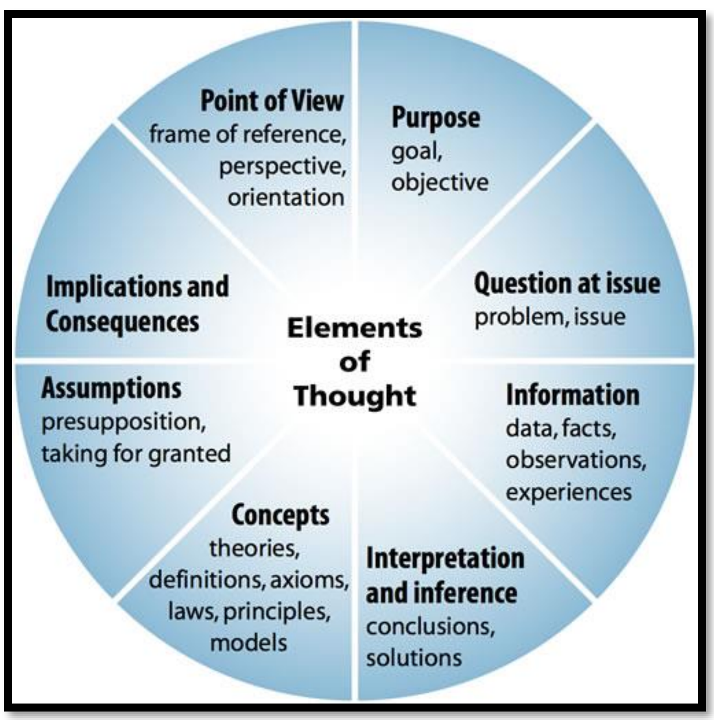


Figure 4. Elements of Thought (Paul & Elder, 2006).

There is no starting or ending point when applying the eight elements; rather, the most beneficial sequence in which to apply the elements depends upon the situation or question being asked (Nosich, 2012). The eight structures each hold implications for the others. For example, if the purpose changes, so does the questions and problems as new information and data will be sought out. *Purpose* reflects an agenda; what the critical thinker is trying to accomplish and what the central aim is. All thought is responsive to the basic structure of thinking through questioning.

To fully understand a thought, the critical thinker needs to understand the *question* that gives rise to it. Questioning the question is key in clarifying the problem and issues at hand. What is the key question that is trying to be answered?

Information provides the facts, data, and experiences that supports and informs the thought. What information is needed to answer the question? *Interpretation and Inferences* draw conclusions and create meaning. Seeking alternatives, providing explanation of one's reasoning, and inquiring as to how conclusions are reached form the basis of this structure within "Elements of Thought".

Concepts define and shape a thought. The theories, definitions, laws, and models that guide and ultimately describe a concept should be closely examined. What is the main idea used in one's reasoning? Is the appropriate concept being used or does the problem need to be re-conceptualized? *Assumptions* challenge the critical thinker to investigate what may be taken for granted. What are the presuppositions present?

Implications and Consequences suggest that all thought is headed in a direction. One must assume that he/she does not fully understand a thought unless the most important implications and consequences that follow from it are known. What is likely to happen if one proceeds in a certain direction?

Point of View refers to the perspectives, orientations, or frame of reference given to a thought (Paul & Elder, 2005). One needs to ask from what point of view the problem is being reviewed. Is there another point of view that should be considered? Which of the possible viewpoints makes the most sense given the situation?

The framework suggests that when an individual carries out the “Elements of Thought” in thinking, he/she develops “Intellectual Traits”. Elder and Paul (1998) suggest that critical thinking is more than simply possessing a set of skills; it involves the virtues of the mind such as intellectual integrity, empathy, humility, courage, and perseverance. Critical thinking suggests the presence of intellectual character. Without intellectual fairmindedness, one will not view situations from multiple perspectives. Without intellectual humility, one will not acknowledge weaknesses in his/her own thinking. Table 4 below provides a list of the common intellectual traits associated with critical thinking along with the definitions.

Table 4

Intellectual Traits and Their Definitions (adapted from Elder & Paul, 1998)

Intellectual Trait	**Definition**
Humility	Having a consciousness of the limits of one’s knowledge; one should not claim to know more than one actually knows
Courage	Having a consciousness of the need to face and fairly address ideas, beliefs, or viewpoints towards which one holds negative emotions
Empathy	Having a consciousness of the need to imaginatively put oneself in the place of others to understand them; to reason from premises
Integrity	Recognition of the need to be true to one’s own thinking; to be consistent in the intellectual standards one applies
Perseverance	Having a consciousness of the need to use intellectual insights and truths in spite of difficulties, obstacles, and frustrations
Faith in Reason	Confidence that one’s own higher interests and those of humankind at large will be best served by giving the freest play to reason
Fairmindedness	Having a consciousness of the need to treat all viewpoints alike, without reference to one’s own feelings or vested interest

The traits of the mind are considered interdependent. For instance, to become aware of the limits of one's knowledge, he/she needs the courage to face prejudices and ignorance. To Elder and Paul's point (1998), individuals must view critical thinking as a pervasive way of being which means continuously probing and assessing thinking in the pursuit of developing intellectual character. Critical thinkers have a questioning inner voice. The art of self-questioning is a crucial component to the development of the traits of mind essential for critical thinking.

The depth, applicability, and foundation offered by the Paul-Elder framework made it the chosen framework for the dissertation study. Assessing the research questions presented in the study, the Paul-Elder framework provided the best supporting mechanism to answer the proposed questions and accomplish the research aims.

Critical Thinking in Healthcare

It is essential to examine how the construct of critical thinking is described, applied, emphasized, and even developed or taught within a discipline. The discipline or professional venue in which this research study resides is imaging science. Imaging science is the profession of producing diagnostic quality images or providing therapeutic procedures to aide in the diagnosis and/or treatment of a multitude of anomalies. The imaging science profession involves various imaging modalities commonly identified as bone densitometry, cardiovascular interventional technology, computed tomography, diagnostic radiology (also known as x-ray or radiography), magnetic resonance imaging, mammography, nuclear medicine, radiation therapy, and ultrasound. The imaging modality of focus for this study is diagnostic radiology. In diagnostic radiology, professionals in the field, known as radiographers or radiologic technologists, use ionizing radiation to produce detailed images of the human body. The radiographer interprets physician orders, positions the patient into various physical orientations to assume the proper projections or views, practices radiation safety principles, controls radiation exposure parameters, utilizes critical thinking to determine the proper protocol and position modifications given a variety of patient conditions, and serves as a patient advocate to explain the exams or procedures and to facilitate communication between the ordering physician, the radiologist reading the images, and the patient. The diagnostic radiology modality was chosen for the study based upon the unique ability for the principal investigator to recruit participants and offer an exclusive and valuable understanding and awareness of the opportunities, limitations, and inherent biases influencing the study outcomes.

Like many healthcare professions, imaging science is faced with the ongoing demand to adapt to a changing workforce environment. Healthcare reform, aging patient populations, dynamic patient needs, changes in technology, and greater awareness of radiation protection guidelines all contribute to the ever-changing demands faced by the radiologic technologist. Critical thinking, both the skills and the dispositions, serves as a mechanism to manage through the evolving work environment. The emphasis for critical thinking is reiterated by the profession's accreditation program standards, professional society's practice standards, and the credential agency's competency requirements. Many educational programs in the discipline of radiography (or diagnostic radiology) follow the accreditation standards set forth by the Joint Review Committee on Education in Radiologic Technology. The standards posed by the accreditation body require programs to document *Student Learning Outcomes* related to critical thinking. "The student will demonstrate critical thinking skills" (JRCERT, 2014, p.16). This emphasis for critical thinking within the profession is further validated by examining the Practice Standards offered by the professional society, American Society of Radiologic Technologists. According to these standards (2016) "Radiographers think critically and use independent, professional and ethical judgments in all aspects of their work" (p. R3). Additionally, the American Registry of Radiologic Technologists communicates the importance of professionals in the field to be critical thinkers. "The purpose of the didactic competency requirements is to verify that individuals had the opportunity to develop fundamental knowledge, integrate theory into practice, and hone affective and critical thinking skills required to demonstrate professional competency" (ARRT, 2016, p. 1). Simply put, best practice for practitioners in the imaging science discipline means thinking critically.

As evidenced by the accreditation program standards, professional society's practice standards, and credential agency's competency requirements, the emphasis for critical thinking is prominent for the discipline of imaging science as it threads from the academic arena to that of clinical practice. The value of critical thinking in healthcare is undisputed as it is a central function for providing quality patient care. While the importance of critical thinking is prominent in the profession, the actual research evidence to suggest how and if critical thinking can be taught to learners in the imaging science field remains void. This deficiency of evidence-based research presents an opportunity for this pilot research study to provide answers and inferences to guide future studies.

Critical Thinking in Education

From nursing to medicine to allied health, there is universal consensus in healthcare education that critical thinking is a required skill and attribute for professionals as evidenced by critical thinking being a key competency in most frameworks for national curricula (Huang, Newman, & Schwartzstein, 2014; Voogt & Roblin, 2012). Despite that, there remains a need for the principles of critical thinking to be explicitly integrated into health professions curricula (Huang et al., 2014; Sharples et al., 2017).

Typically, professional healthcare educational programs focus on the acquisition of discipline-specific knowledge enriched by clinical experiences (Bartlett & Cox, 2002). The need for critical thinking curriculum is becoming more prevalent in an effort to enhance knowledge application in both didactic and clinical settings.

Teaching Strategies for Critical Thinking

Literature suggests that strategies used to teach critical thinking are often ineffective if taught through a traditional, lecture-based design where the learning is passive (Alexander, McDaniel, Baldwin, & Money, 2002; Biley & Smith, 1998). Instead a more non-traditional design approach where active learning places takes is more effective given the complexities of critical thinking (J. Lee, Lee, Gong, Bae & Choi, 2016). Active learning allows the student to construct his/her own learning; it is learning by doing (Freeman et al., 2014). The student is more effectively engaged when the learning is active. The learner is able to reflect upon the ideas presented, and is able to self-monitor his/her own understanding of the concepts at hand (Michael, 2006).

There is a large body of literature offering numerous instructional design strategies to explicitly teach critical thinking; however, two commonly used strategies stand out in medical education research. Dating back to 1900s, research offered problem-based learning or PBL as a primary learning activity to foster critical thinking. The idea of PBL was first introduced at the McMaster School of Medicine in Canada in 1965 (Berkson, 1993). It was later advanced by Dr. Howard Barrows as both a curriculum strategy and a process approach in 1988 (Kong, Qin, Zhou, Mou, & Gao, 2014). Since the initial introduction of PBL into the academic arena, additional evidence-based research has supported the effectiveness of PBL in teaching critical thinking (Margetson, 1997; Maudsley & Strivens, 2000; Tiwari, Lai, So & Yuen, 2006). PBL is a student-centered approach to learning in which small groups work collaboratively to resolve a problem or defined situation (Rideout & Carpio, 2001). In the problem-based learning process, there are five key steps: analysis of problems, establishment of learning objectives, collection of information, summarizing, and reflection (Lin, Lu, Chung, & Yang, 2010).

Reflective writing, or journaling, is another pedagogical strategy offered in literature to support the explicit teaching of critical thinking (Craft, 2005; Heinrich, 1992; McGuire, Lay, & Peters, 2009; Naber & Wyatt, 2014; Rooda & Nardi, 1999). Writing can help to increase critical thinking skills, particularly when the writing activity is structured around the Paul-Elder framework (Broadbear & Keyser, 2000; Reed & Kromrey, 2001). The aim of reflection is to develop self-awareness, insight, and to explore alternative perspectives (Coleman & Willis, 2015). Reflective writing is the mechanism from which an individual can learn from his/her experiences (Rolfe, Freshwater, & Jasper, 2001). By combining first-hand learning with critical thinking and new knowledge, reflection can propel learners to challenge previous assumptions (Howatson-Jones, 2010; Taylor, 2003). The ability to learn from experiences and question previous assumptions, as fostered by the reflective writing activity, supports critical thinking behaviors within the individual learner. Reflective writing can serve to prepare the learner for professional development as healthcare professionals rely on these skills, reflection and writing, to effectively carry out the responsibilities of their position (Jasper, Megan, & Mooney, 2013).

While there is sound, vast literature associating reflective journaling with teaching critical thinking, the research is vague and limited in terms of what the actual components of the journal assignment entail (Heinrich, 1992). This gap in literature presents an opportunity for this dissertation research to provide evidence as well as a concrete example of the detailed components of a reflective journal assignment aimed to teach critical thinking.

Assessment of Critical Thinking

A paradigm shift in higher education is underway changing the focus from curricular content to curricular outcomes, or more prevalently referred to as “competency-based” curriculum in healthcare education. The emphasis for teaching critical thinking creates the need for reliable and valid methods of measuring critical thinking (Karbalaei, 2012). Educators need to be able to assess whether or not the teaching methodologies they employ are effective in achieving student competencies. Measurement tools related to critical thinking provide a gauge for reaching the desired outcomes. Commercial tools are available to measure students' critical thinking abilities.

The Watson-Glaser Critical Thinking Appraisal (WGCTA) is a commonly used tool in the nursing discipline to measure logical and creative components of critical thinking. The WGCTA tool uses problems and arguments similar to those that would occur in actual nursing practice (Karbalaei, 2012). The measurement tool is a 50-point item, self-administered exam generating a score indicative of critical thinking ability (Watson & Glaser, 1964).

A second commonly used tool to assess the measurement of critical thinking skills is the California Critical Thinking Skills Test (CCTST). This frequently utilized tool has a strong evidence-based foundation with the nursing discipline; however, the questions posed by the test are not discipline-specific making the test usable by a student from any profession (P. Facione & Facione, 1992). There is literature from the following professions that have utilized the CCTST in measuring critical thinking skills: nursing, medicine, dentistry, and allied health (Domenech & Watkins, 2015; Lee et al., 2016; Ross et al., 2016; Tsai, 2014). This assessment is well-validated in healthcare literature evidenced by a PubMed search of "CCTST" yielding 41 studies from 1997-2017. The newest version of the California Critical Thinking Skills Test is a 100 point, multiple-choice assessment. The test uses authentic problem situations to assess core critical thinking skills (Karbalaei, 2012). The CCTST is based upon the Delphi consensus definition for critical thinking.

For the dissertation study, the CCTST will be utilized to measure the change in critical thinking scores of participants. While the Watson-Glaser Critical Thinking Appraisal is a well-known, utilized assessment in the nursing discipline, the literature is lacking on its applicability to the field of imaging science. The California Critical Thinking Skills Test is designed to be universally applied across disciplines. For this reason, plus the alignment with the Delphi consensus definition, it was the optimal measurement tool for the dissertation study.

Literature Review Summary – Connecting the Pieces

The literature review section explored the various definitions for critical thinking. While there are many definitions in literature available, the definition provided by experts in the Delphi consensus project has been repeatedly validated by research, and therefore, was the chosen definition to guide the dissertation. The definition identified two key dimensions for critical thinking: cognitive skills and affective dispositions. The cognitive skills and affective dispositions for critical thinking were then applied to the day-to-day functions and professional requirements of radiologic technologists. It is evident from the professional code of ethics, accreditation mandates, and practice standards for certification and registration that radiologic technologists need to be critical thinkers. With the healthcare professions demanding that practitioners exhibit critical thinking behaviors, educators are left to determine how to guide learners into the best practices of critical thinking. Curricular reform, to address the demand for critical thinking in an ever-present changing workforce, is essential to reaching desired outcomes and student competencies related to critical thinking. Teaching strategies are provided in literature to guide the educators on how best to accomplish these desired outcomes. Reflective journaling is a common, evidenced-based methodology for students to acquire critical thinking skills. This learning activity is proven to be effective in teaching critical thinking. Once the learning strategy is in place, educators need a measurement tool to determine if and how much change has occurred as a result of the strategy implemented. The CCTST is a research-supported assessment tool to provide those answers and to ultimately gauge changes in critical thinking skills. It is important in research for there to be a connection between definition, framework, learning strategy, and assessment. These pieces need to be linked and have a thread of consistency among them so the research outcomes are trusted and reliable by the end users.

CHAPTER 2: CURRENT PRACTICES

This unique chapter details a research study conducted to examine current educational practices related to critical thinking as employed by radiography programs.

Introduction

Educational programs in the field of imaging science are faced with the ongoing demand to prepare students for a profession that will remain in a state of constant change. From healthcare reform to aging and expanding patient populations to technology advances, the need for future imaging professionals to adapt to the unknown has become an essential attribute for successful practice. The knowledge and skill set needed to adapt to these evolving work conditions are strongly associated with the ability to think critically. Being equipped with a critical thinking framework in unfamiliar circumstances and the practice time to apply the underpinnings of a framework will promote best practices for the future professional.

While the need for future professionals to demonstrate critical thinking is evident, the problem resides in whether or not educational programs are providing students with a foundation in critical thinking, such as through an expert-supported framework coupled with the learning activities to put the framework into practice. Existing literature provides a definition for critical thinking and the learning activities to promote the construct, but there is a gap in literature targeting current practices of radiography educational programs to foster critical thinking. Filling this gap will heighten awareness and prompt opportunities for curriculum reform as it relates to promoting critical thinking.

Statement of the Problem

A review of existing literature in the field of imaging science confirms that the profession is deficient as compared to medicine and nursing in terms of identifying effective critical thinking teaching methods and ultimately incorporating these methods into the curriculum. Effective learning strategies tend to foster active learning, place the student at the center of the learning, and promote synthesis and application of knowledge (Kowalczyk, Hackworth, & Case-Smith, 2012; Kowalczyk & Leggett, 2005). It is probable to assume that most educators aim to foster critical thinking among students, but the evidence to support what educational strategies are most effective in teaching critical thinking remains of value. More evidence is needed in the field of imaging science so educators can effectively prepare future professionals to be critical thinkers. Examining the current educational practices is a starting point toward accomplishing this goal.

Research Questions

Literature provides definitions for critical thinking, commonly used critical thinking frameworks, and educational strategies incorporated within a curriculum to teach critical thinking. In imaging science education, the current state of literature pertaining to critical thinking presents a vast opportunity for research. This void in literature provokes the following research questions guiding this study:

- What are the current educational practices utilized by radiography programs to teach critical thinking?
- Are programs using a specific framework within the curriculum to foster the development of critical thinking? If so, what frameworks are being used?
- Do program directors feel there is value in teaching critical thinking to students?
- How are students currently acquiring their critical thinking behaviors?

Since there is little data published regarding the educators' perceptions and teaching strategies for critical thinking in radiography programs, there is great value in learning more about how programs are handling the demands of assessing a crucial student learning outcome: critical thinking. This data offers awareness for educators to examine if peer educators are placing value on critical thinking and if there are commonly used frameworks to guide teaching methodologies. By knowing what is currently happening among peer programs, educators can make more informed decisions regarding curriculum reform aimed at teaching critical thinking.

Methodology

The purpose of the study was to identify and explore the current educational practices for critical thinking by radiography programs. A survey was used to collect data related to program demographics and critical thinking educational practices. The project was submitted and approved by the University of Nebraska Medical Center's Institutional Review Board in 2016.

Participants

The targeted participants in the study were radiography program directors following programmatic accreditation with the Joint Review Committee on Education in Radiologic Technology (JRCERT). This group was selected for participation because the participants would have the knowledge and expertise to best answer the research questions posed. Additionally, JRCERT standards require programs to assess student learning outcomes related to critical thinking skills. At the time of the research project implementation phase, all 606 radiography programs programmatically accredited by the Joint Review Committee on Education in Radiologic Technology were invited to participate in the study. Institutions participating in the survey represented both degree-granting and certification radiologic sciences programs. The program directors' names and email addresses were collected from the JRCERT database available through the website.

Instrumentation

The survey content was designed to answer the proposed research questions through quantitative measures and qualitative reflections. The survey used was an original instrument, not previously validated in literature. The formatting of the questions provided a mix of closed-ended and open-ended questions. The closed-ended questions offered quantitative data where statistics were used to evaluate the responses, while qualitative reflections where captured through open-ended questions that allowed participants to elaborate on responses. The overall design approach was mixed methods, placing primary emphasis on quantitative data using qualitative, open-ended data for additional clarification or expansion of answers leading to a rich understanding of the current educational practices. For example, one survey question asked participants…"Do you feel there is value in teaching a critical thinking framework to your radiography students? a. Yes b. No". The number of "Yes" and "No" responses were collected and tabulated to generate the number of programs that did and did not perceive value in teaching critical thinking. The follow up, open-ended question stated…"Based upon your response to the previous question, please tell me why you feel that there is or is not value in teaching a critical thinking framework to your radiography students". This open-ended, text response allowed the participant to expand upon his/her perceptions regarding value for teaching a critical thinking framework.

The first section of the survey questionnaire provided program demographic information. The second section examined the clinical component of the program's curriculum. The final section, and the most robust in number of questions, pertained to critical thinking – perceived value, current educational practices, framework used, and assessments used to measure critical thinking learning outcomes. See APPENDIX A: CURRENT PRACTICES SURVEY.

Data Collection and Analysis

An email notice was sent to all programmatically accredited radiography directors in the United States as identified by the JRCERT database. An embedded cover letter with electronic link to the RedCap survey was provided to the eligible participants. The cover letter offered full disclosure about the intent and design of the study. The letter stated that participation was voluntary, no risks or benefits were associated with participation, and that participants could withdrawal from the study at any point in time. Implied consent was secured through submission of the survey. Reminder emails were sent at approximately one and three weeks following the initial invitation for participation. All data was collected through the Research Electronic Data Capture, “RedCap”, survey tool powered by Vanderbilt (https://projectredcap.org/software). Data was analyzed utilizing statistics to include the means and percentages for the responses to the closed-ended questions.

Results

Demographics

A total of 606 program directors were contacted for participation in the research study. After three email reminders to prompt participation, a total of 195 programs were represented in the data. The research efforts yielded a 32 percent response rate. Program demographics in reference to the terminal award offered are found in Table 5 below, followed by Table 6 showing average matriculant, or entering, class size for the participating programs.

Table 5

Program Demographics by Terminal Award Offered

Number of Programs	Terminal Award
135	Associate Degree
25	Bachelor
35	Certificate

Table 6

Program Demographics by Average Matriculant Class Size

Number of Programs	Matriculant Class Size
29	0-10
100	11-20
66	21+

Radiography programs tend be structured in one of two curricular approaches; the first is structured with simultaneous didactic instruction and clinical placement and the second is designed to begin with didactic instruction then follow with clinical placement. Table 7 shows the program numbers in terms of curriculum structure.

Table 7

Program Demographics by Curriculum Structure

Number of Programs	Curriculum Structure
170	Didactic and Clinical Placement Congruent
25	Didactic Before Clinical Placement

Clinical Component

Survey participants were asked to indicate how quickly students were integrated into the clinical environment where they are assisting in direct patient care in a non-simulated environment. See the pie chart in Figure 5 for a breakdown of the responses.

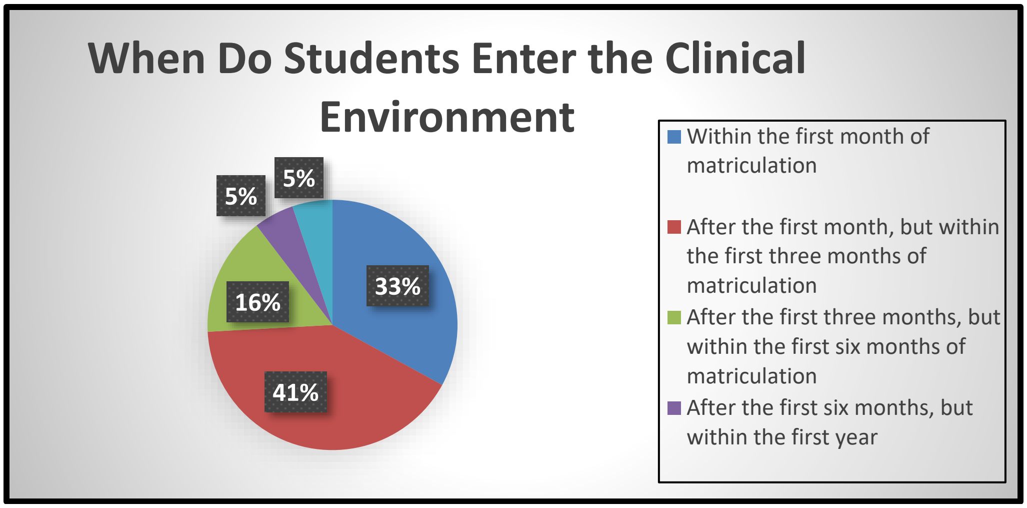


Figure 5. Percentage distribution of responses for when students enter the clinical environment.

Additionally, program directors were asked the timeframe in which students were placed in clinical environments considered more "problem-solving prone", such as the emergency department (ED), operating room (OR), and the weekend/evening shift. The response options were as follows: within the first month, after the first month but within the first three months, after the first three months but within the first six months, or after the first six months but within the first year. See the pie chart in Figure 6 below for a visual distribution of the responses.

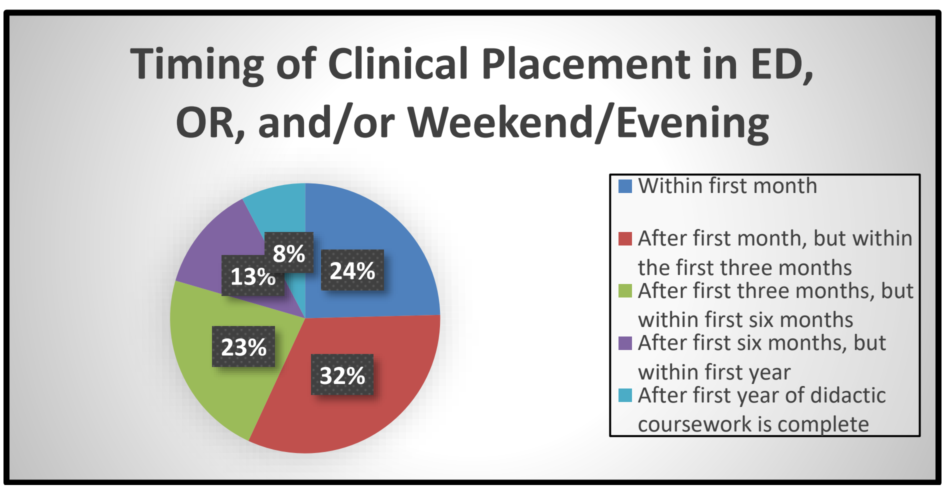


Figure 6. Percentage distribution of responses for clinical placement timing in the emergency room, operating room, and/or weekend/evening shifts.

Critical Thinking – Perceived Value and Curriculum Integration

When participants were asked whether or not a specific critical thinking framework was taught to students within the curriculum, 84 percent responded “No” while the remaining 16 percent responded “Yes”. For those that indicated “Yes”, an open-ended question was prompted for the participant to indicate the specific framework that was utilized. Some of the qualitative responses provided learning activities related to critical thinking versus specific models or frameworks. Models or frameworks offered in the responses were Kolb’s Theory of Experiential Learning, Reflective Judgment Theory, Bloom’s Taxonomy, Paul-Elder framework, and Steps in Critical Thinking and Problem Solving by Adler and Carlton.

Survey data indicated a notable 89 percent of programs perceive value in teaching a critical thinking framework to students. Qualitative responses regarding why participants perceived value in a framework included the following: preparing the students for real-world practice, students will need to make adjustments in their work environments, and the profession requires judgments and decision making that impact patient care. A direct quote from an educator stated, “It is valuable because it helps students apply what is learned in the classroom to the real-world setting, but also sets them up to adapt that knowledge to situations that are not straight from the textbook”. Another participant stated, “I think that there is value in teaching a critical thinking framework. Radiographers must be able to think critically in order to make adjustments in the clinical setting. I think that a framework would assist them”.

Participants were asked to rank in order of importance, “From which of these avenues do you believe students will gain the most critical thinking behaviors?” The provided avenues, or learning mechanisms, which best facilitate critical thinking behaviors were: didactic classroom instruction, clinical experiences, learning activities such as case study analysis or journaling, and knowledge of a critical thinking framework. See Figure 7 for the ranking of avenues.

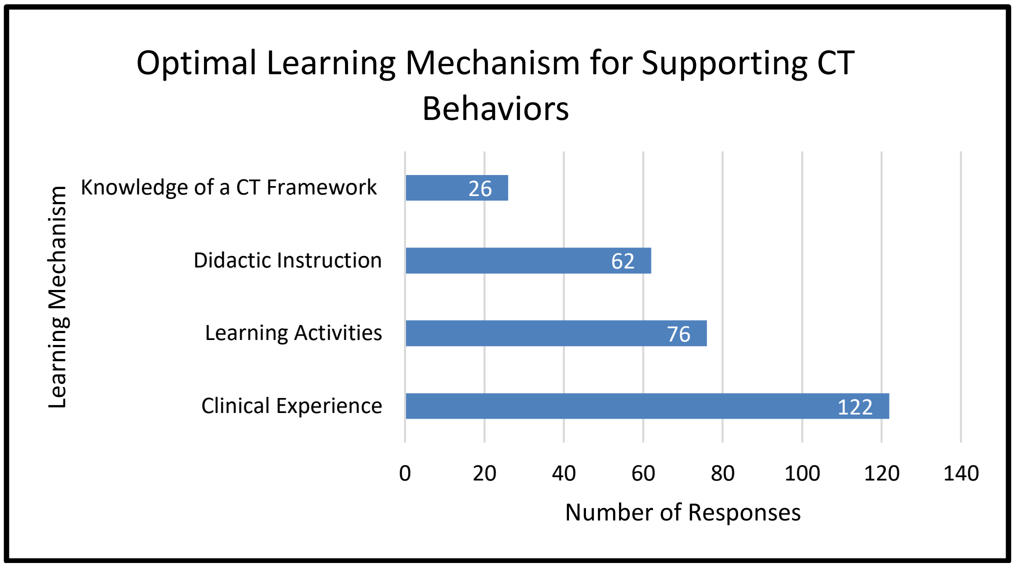


Figure 7. Perceived optimal learning mechanisms to support critical thinking behaviors.

The distribution of perceived importance heavily favored clinical experiences (hands-on involvement in clinical procedures) as the most prevalent avenue with knowledge of a critical thinking framework as the least prevalent mechanism. Responses for learning activities (such as case study analysis or journaling) and didactic classroom instruction were very similar, both of which were about half as common as clinical experience.

At 91 percent, the vast majority of programs indicated that educational activities within their curriculum specifically aim to promote critical thinking behaviors. When asked what educational activities are used to accomplish this objective, the participants were instructed to select all responses representative of their program's learning activities. See Figure 8 below.

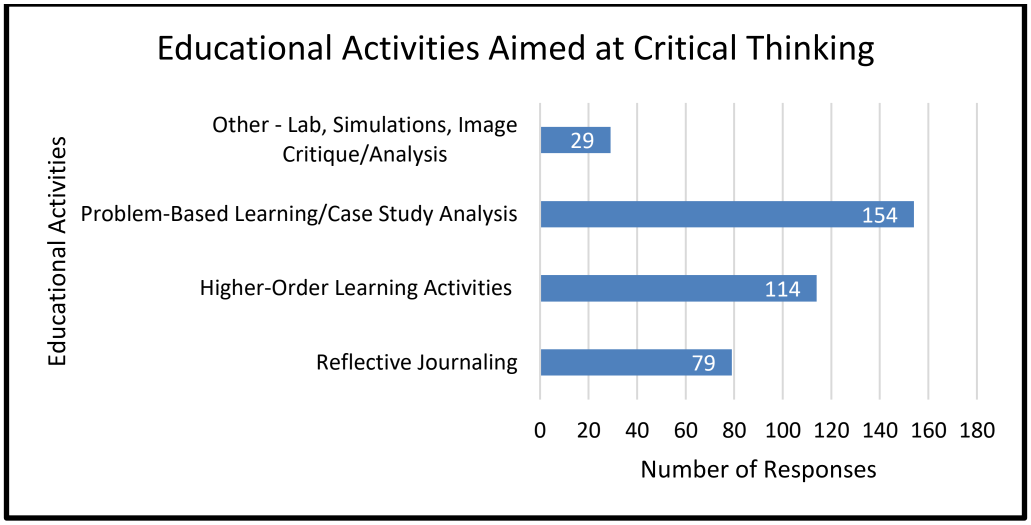


Figure 8. Educational activities used by programs to promote critical thinking.

Discussion

This study has provided quantitative data and qualitative reflections which provide a deeper understanding as to what radiography programs are currently doing to teach critical thinking. Additionally, the survey responses showed strong evidence for the importance of teaching critical thinking, which provides evidence for the need of future research on critical thinking within the field of imaging science.

Research Question One

The first question this research study aimed to address was: What are the current educational practices utilized by radiography programs to teach critical thinking? Studies in literature indicated the need for all healthcare professionals to practice in the field using critical thinking skills and dispositions. While literature exists in the medical and nursing professions related to critical thinking, the imaging science discipline has lagged behind. With the data generated from this study, more is known about the current educational practices in radiography. Results indicate that programs rank problem-based learning/case study analysis as the most commonly used educational activity for fostering critical thinking. These findings correlate with the literature found in nursing and medical education journals, suggesting the potential application of these outcomes to imaging science. Follow up research could be conducted to confirm this theory.

Research Question Two

The second research question guiding the study was: Are programs using a specific framework within the curriculum to foster the development of critical thinking? If so, what frameworks are being used? The survey results suggested that a resounding percentage of programs did not use a specific critical thinking framework. For those that do use a framework, two of the commonly referred to frameworks found in the literature review were indicated as Bloom's Taxonomy and the Paul-Elder framework.

Research Question Three

The third question raised by the study was: Do program directors feel there is value in teaching critical thinking to students? An overwhelming 89 percent of respondents indicated there was value in teaching critical thinking to students. The strong indication of value for teaching critical thinking compared to the low percentage of educators actually utilizing a specific critical thinking framework suggests there is an opportunity for additional research to investigate the effectiveness of using a framework to teach critical thinking in imaging science.

Research Question Four

The final question posed in this study was: How are students currently acquiring their critical thinking behaviors? The data showed that programs are using a variety of teaching mechanisms from clinical experiences to learning activities (such as reflective journaling) to traditional didactic instructional modes of content delivery to teach students about critical thinking behaviors. The highest ranking mechanism for learning critical thinking as suggested by the results was clinical experience. Programs are relying heavily on clinical experiences as a means of building and applying acquired critical thinking behaviors. Clinical experiences ranking at the forefront of educational practices is supported by the bulk of programs placing students in the clinical environment within the first three months of matriculation. Additionally, the importance of clinical experiences is validated by the majority of programs following a curriculum structure where the didactic component occurs in conjunction with clinical placement. The notion of clinical experiences fostering the development of critical thinking is not unique to the field of imaging science. The importance of these real-world experiences in prompting critical thinking has been supported in literature (Bartlett & Cox, 2002; Maynard, 1996; McCarthy, Schuster, Zehr, & McDougal, 1999).

Recommendations for Future Research

Overall, the quantitative data and qualitative explanations collected in the survey suggest that while programs value critical thinking and want their students to demonstrate the associated behaviors and dispositions, there exists an opportunity to examine the value of a specific critical thinking framework incorporated into the curriculum. There was no gold standard framework universally identified by the educators. Given the low number of responses indicating that a specific framework was taught within the curriculum, there appears to be an opportunity for future research to investigate the effectiveness of certain frameworks or models within radiography curriculum. Moreover, while programs emphasize the importance of critical thinking, there appears to be an assumption that current learning activities are, in fact, promoting the acquisition of critical thinking. Is critical thinking explicitly being taught? How are programs measuring any progression in critical thinking resulting from the learning activities they employ? Research suggesting that changes in critical thinking assessment data can occur as a direct result of deliberate learning activities would be advantageous to the field. Educators want to know that the potential pains of curriculum reform yield positive gains in the end.

Conclusion

Examining the current educational practices promoting critical thinking is the first step in moving academic initiatives and outcomes forward. Armed with data supporting current practices or to propose an opportunity for change, educators gain a greater understanding and awareness of learning activities related to critical thinking from fellow educators. This data provides an indication of what programs are currently doing to address the need for students and future practitioners to be critical thinkers. Future researchers can utilize the findings of this study to investigate the next phase of questions such as: What frameworks are most effective in teaching critical thinking to radiography students? What assessment measures are reliable in validating when change in critical thinking has occurred? and How can a critical thinking framework be implemented within a curriculum? From research findings, new research questions arise.

Critical thinking is and will likely always be an essential attribute for a successful practitioner in imaging science. Educators, credentialing agencies, professional organizations, and programmatic accreditors all acknowledge the importance of students and practitioners demonstrating critical thinking behaviors in the field. On a routine basis, radiologic technologists are making judgments relative to patient care, adjusting protocols, practicing radiation safety principles, and determining the optimal approach to achieving quality images given a multitude of varying conditions and circumstances.

Critical thinking facilitates these best practices and ultimately leads to optimal patient care. Educational programs have an opportunity to foster critical thinking behavior by implementing learning activities explicitly aimed to develop these skills in their students. These deliberate learning activities will then translate into future best practices.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

Research Design

The purpose of this dissertation study was to investigate whether an educational intervention utilizing a deliberate pedagogical strategy aimed at teaching critical thinking to radiography students was effective as supported by changes critical thinking scores and the reflections of participants.

Research Question One (Quantitative): Was the chosen educational intervention proven effective as determined by comparing changes in scores on a critical thinking assessment tool between the experimental and control groups?

Research Question Two (Qualitative): How did the qualitative data generated from the journaling and the participants' post-intervention reflections enhance the overall understanding of the intervention's effectiveness in teaching critical thinking?

Research Question Three (Mixed Methods Integration): What conclusions can be made regarding the effectiveness of the intervention when the two data sets, quantitative and qualitative, merge together?

A mixed methods design approach was used to answer whether or not the educational intervention was effective as evidenced by changes in critical thinking scores and participants' reflections. The very nature of the study's purpose aligns with a mixed methods approach as both quantitative and qualitative data are needed to yield an in-depth understanding of the complex phenomenon at hand. To fully answer the research questions posed in the dissertation study, neither quantitative nor qualitative methodology alone would suffice (Creswell, 2015). Data essential to understanding the effectiveness of an intervention aimed at teaching critical thinking relies on both sets of data, and moreover, the integration of the two data sets.

The complexity of critical thinking, where it entails both cognitive skills and affective dispositions, suggests the need for both quantitative data to determine the changes in critical thinking scores and the qualitative data to examine the reflections and experiences from participants. The critical thinking scores provide quantitative evidence for the intervention's effectiveness in teaching critical thinking but often numbers alone leave unanswered questions which can only be answered through qualitative data. The qualitative data found in journal reflections and open-ended survey responses ultimately enriches the understanding of the intervention effectiveness; these words offer meaning behind the numbers. Similarly, without the quantitative data, there would be questions as to the actual changes in scores that measure the cognitive skill facilitated from the intervention. While experiences can be perceived as positive, the numbers ultimately provide quantitative evidence to support or contradict the perceptions. In the end, by merging the numbers with words and integrating the two data sets, the research design produces a more complete picture.

This study used an advanced mixed methods design: intervention with added elements of the convergent and explanatory design approaches. According to Creswell (2015), the intent of the intervention design is to investigate a problem by conducting an interventional trial and adding qualitative data into it. Qualitative data can be collected before, during, and after an intervention and integrates it through embedding. For this dissertation study, qualitative data will be collected both during and after the intervention. The qualitative data collected during the intervention alludes to the convergent design, where there is a concurrent but separate collection of quantitative and qualitative data. When analyzing the data sets in the convergent design, the researcher attempts to explain or resolve any conflicting findings. The researcher analyzes to what extent the two data sets converge. Meanwhile, when the qualitative data is collected after the intervention, this is suggestive of the explanatory design, where qualitative data is collected to explain the quantitative data in greater detail (Creswell, 2015). Figure 9 below provides a diagram for the intervention mixed methods design using both convergent and explanatory components, which guided the dissertation study.

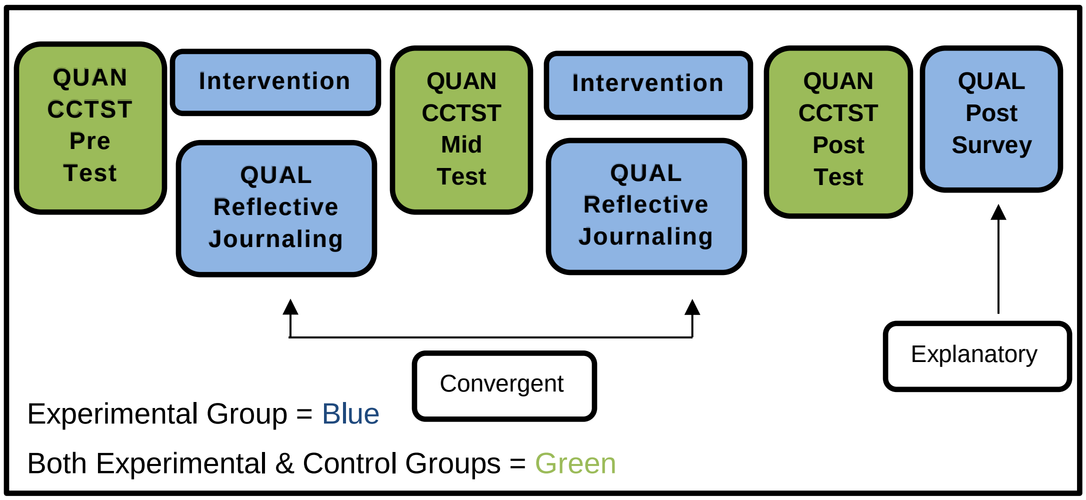


Figure 9. Intervention mixed methods design with elements of convergent and explanatory design features as indicated by arrows (adapted from Creswell, 2015).

Intervention

The educational intervention used in the dissertation consisted of a two-phase design. The first part of the intervention introduced an online critical thinking learning module to the experimental group of participants, designed by the study researcher for participants to complete in an approximately 15-20 minutes. The learning module was built upon the Paul-Elder critical thinking framework. The module defined critical thinking, detailed the importance of critical thinking, introduced and explained the Paul-Elder framework, described how the framework could be applied through reflective journaling, and using an example demonstrated how the journaling exercise would be carried out in a real-world, clinical scenario. The example provided the student participant with a completed model in which to guide his/her own application efforts. The aim of the first phase of the intervention was to introduce and scaffold the student participant into what critical thinking was, explain how to work through critical thinking situations utilizing the framework, and record those processes through reflective journaling. See Figure 10 for a representation of the module content.

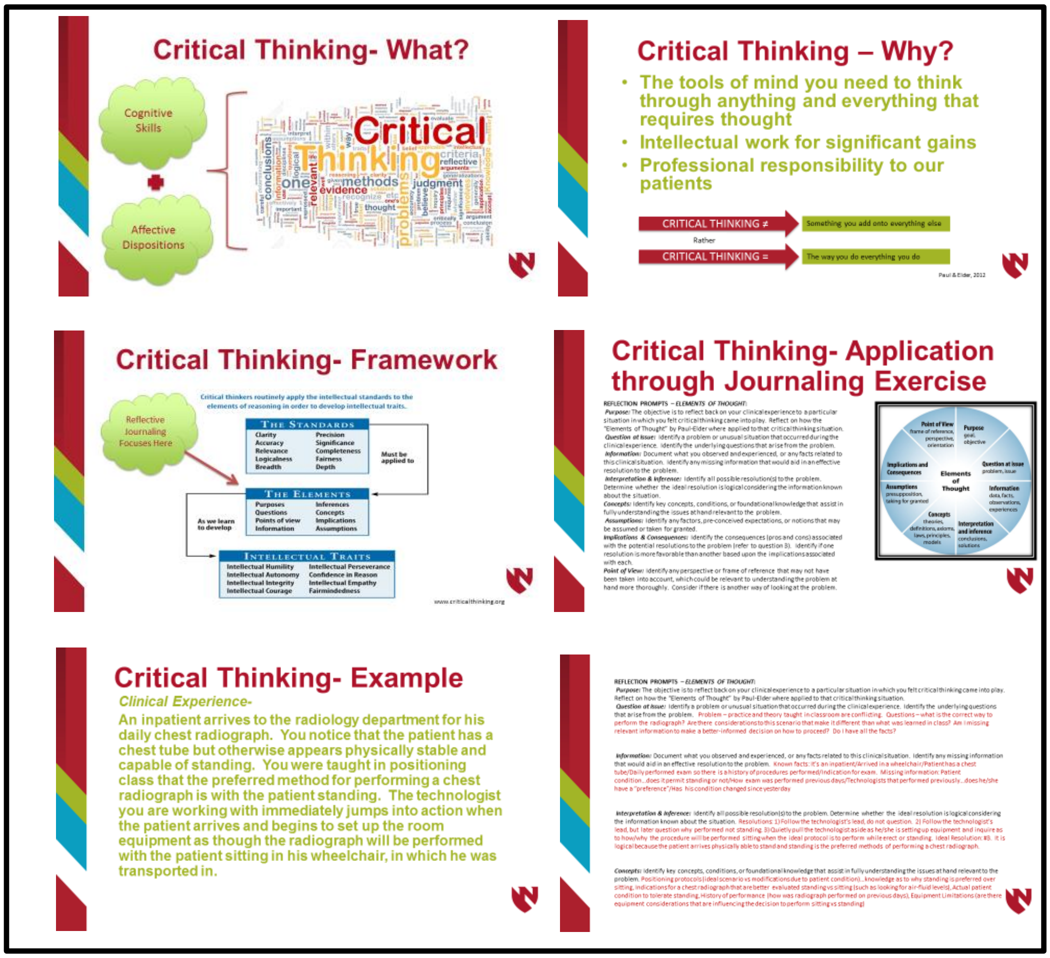


Figure 10. Critical thinking content covered in the module.

After completing the module, the second phase of the intervention started. The experimental group was asked to report on critical thinking moments when assigned to specific clinical rotations such as: emergency department, operating room, and/or the weekend/evening shift. These moments were recorded on a reflective journal document designed to prompt the user to apply the elements of the Paul-Elder critical thinking framework to a critical thinking situation. The journal document used in the dissertation is found in APPENDIX B: REFLECTIVE JOURNAL.

Specific clinical rotations identified as: emergency department, operating room, and/or the weekend/evening shift were selected to condense the amount of writing assignments and more importantly to align the journaling with those clinical rotations that tend to offer the greatest number of critical thinking moments. In the field of imaging science, the emergency department and operating room environments pose the greatest opportunity for problem-solving, making judgments, and assessing unique patient conditions. Moreover, the weekend/evening shift tends to prompt more decision-making and judgment due to upper management not typically being readily available to directly problem-shoot issues. These opportunities, innately presented by the selected rotations, made them the prime environment to apply the Paul-Elder framework. Each student had approximately two to three rotations (a rotation is defined as one week or 16 hours of clinical time) in the selected clinical areas per semester. The amount of clinical exposure to these critical thinking “prone” rotations was consistent between the experimental and control groups. The experimental group did not deliberately receive more rotations in these critical thinking-prone areas than the control group. The experimental group was asked to submit reflective journals following the targeted rotations during the fall and spring semesters; each semester was approximately 16 weeks in length. The entire timespan of the intervention was approximately nine months.

The aim of the reflective journaling activity was two-fold. The first aim was to have the participant actively apply the concepts of the framework through reflective journaling, which is validated by literature as being an educational strategy effective in teaching critical thinking. The second aim of the reflective journaling was to examine the journal writing to gather the thoughts, perceptions, and experiences offered through qualitative data. This second aim aligns with the convergent mixed methods design approach, where data was being collected during the intervention. The journal writing was used both as a learning mechanism and as qualitative data to offer insight related to the overall understanding of how effective the intervention was at teaching critical thinking as viewed by the participants.

Quantitative Data

The quantitative strand must follow a rigorous process from design to data collection to data analysis that minimizes threat to validity and reliability of the study. The findings need to be reliable, clearly connected to the evidence, with the ultimate aim to answer the quantitative research questions. Deliberate care was taken to assure that the quantitative data was a direct reflection of the participant’s measure of critical thinking.

The quantitative data used in the study was generated from the California Critical Thinking Skills (CCTST) assessment. As mentioned in the literature review chapter, the CCTST assessment tool was chosen as the quantitative instrument in this study because it is well-supported in healthcare literature as being a reliable tool to use for measuring critical thinking. Moreover, it follows the Delphi consensus definition for critical thinking, which has been interwoven throughout the study from the literature review to the research design in utilizing the Paul-Elder framework, and finally to the assessment of critical thinking.

In order to account for any changes in critical thinking innately arising from clinical experiences and progression through the program curriculum, the quantitative data was collected at three intervals: pre-, mid-, and post-intervention stages. The pre-test took place at the onset of the professional curriculum. The mid-test was administered upon completion of the first semester of the professional curriculum. The post-test was conducted upon completion of the second semester of the professional curriculum. These data points, at three intervals, serve as a comparison point to gauge when the most prominent changes in scores occurred. All participants, both experimental and control, completed the three assessments at the same time and under the same testing conditions. Effort was made to minimize any controllable variables between the groups for the quantitative strand of the research study.

Qualitative Data

It is essential that the qualitative methodology establishes trustworthiness through truth value, applicability, consistency, and neutrality. These central components can be approached through strategies of credibility, transferability, dependability, and/or confirmability (Krefting, 1991). Table 8 below indicates the criterion performed in an effort to establish trustworthiness in the qualitative phase of the research.

Table 8

Summary of Strategies which Promote Trustworthiness (adapted from Krefting, 1991)

Strategy	Criteria
Credibility	***Reflexivity*** - Researcher is intimately aware of the phenomenon at hand through personal experiences; however, can generate meaningful questions for the follow-up survey and yet remains aware of any potential biases and preconceived assumptions
Transferability	***Selection of Informants for Generalizability*** - The sample group selected for the qualitative portions of the study will be the entire experimental group; therefore, all experiences and reflections of the individuals participating in the intervention will be captured.
Dependability	***Code-Recode Procedure*** - A segment of the data will be analyzed, then reanalyzed after a delayed period of time to compare the results.
Confirmability	***Audit*** - A review committee has examined the research plan to determine how decisions were made and whether similar conclusions would result. ***Qualitative Research Expertise*** - Knowledge base of proper qualitative procedures and research design implementation which strengthens the trustworthiness of the design and outcomes.

The qualitative data for the dissertation was gathered from two sources: reflective journals and the post-intervention survey. As mentioned in the literature review section, reflective journaling has been supported by literature as to its direct correlation with teaching critical thinking. The value of the journaling activity was two-fold in that it is an educational strategy for developing critical thinking and that the data itself was extrapolated to offer insight as to the perceptions, personal experiences, and thoughts of the research participants. The post-intervention survey captured the experiences and perceptions of participants approximately six months post intervention.

Selection of Subjects and Setting

For this pilot study, convenience sampling was used to recruit participants. Given the unique position of the researcher as director of the radiography program, students from the junior cohort of the University of Nebraska Medical Center's radiography program were invited to participate in the study. This group of students was readily accessible to the researcher, provided a convenient sample, and yet offered a valuable source of data to generate quality answers to the research questions posed. The students, though convenience sampling, provided the needed answers for this pilot study to guide future, more expansive studies. The imaging science profession is severely limited in literature pertaining to the best educational practices for teaching critical thinking. Despite the number of participants in the pilot study, the findings generated will greatly advance and undoubtedly impact the field of imaging science. It is also important to note that the sample number used in the study was representative of radiography program enrollment numbers throughout the United States.

The inclusion criteria for participation in the study was enrollment in the University of Nebraska Medical Center's radiography program at the junior level. The purpose of selecting participants at the junior (or entry) level was to minimize prior experience and learning activities which may have fostered critical thinking. The aim was to capture participants at a baseline level of cognitive skill and affective dispositions relative to critical thinking in order to tie any change in critical thinking measures and perceptions associated with the intervention directly to its effectiveness.

The participants were undergraduate level students who matriculated into the professional program with approximately 50 general education prerequisite semester hours. The research sample represented students from the three program campuses: Columbus, Kearney/Grand Island, and Omaha, all located in the state of Nebraska. The gender and ethic demographics were representative of the profession and the state, with the majority of the students being Caucasian, female. The average age of the participants was 21. Most entered the radiography program with some job shadowing experience in the field, estimated at eight hours.

All 20 eligible students volunteered to participate in the study. From the consents received, the researcher randomly selected 10 students for the experimental group and 10 students for the control group. All 20 participants remained in the study until completion. The experimental group took the pre, mid, and post CCTST tests, participated in the intervention (module completion and reflective journaling), and submitted a post-intervention, open-ended survey. The control group took the pre, mid, and post CCTST tests.

The setting for the research study varied. For the learning module portion of the intervention, an online platform was used. Each participant had a private log-in and password feature to access the module, validating that the intended user completed the learning module. As a result of using the online platform, the environment in which the experimental cohort viewed the module was not controlled or set. This also applied to the actual writing phase of the reflecting journaling activity. Participants conducted the writing in their own preferred space and time. The purpose for this approach was to encourage in-depth, elaborative writing. For the CCTST assessments, a controlled testing environment was utilized for administration and proctoring oversight. All participants, both experimental and control, utilized their personal laptops to take the online assessment. Both groups were active in clinical rotations as part of the professional curriculum. Clinical rotations were completed at various clinical affiliate sites. There was no opportunity to control or influence the clinical environment as each site has a unique patient volume, variety of exams, and set protocols. Detailed instructions were provided to align the reflective journaling activity with clinical rotations designated in the emergency department, operating room, and/or the weekend/evening shift.

Data Collection Procedures

Permission to conduct the research study was received from the University of Nebraska Medical Center's Institutional Review Board (IRB). See APPENDIX C: IRB APPROVAL. Upon receiving IRB approval, eligible students were informed of the study via verbal communication. Students were given a full description of the research project to include: purpose of the study, disclosure that no risks were associated with the study, withdraw procedures, contact information, statement of voluntary participation, and generalization of results so individual journals or scores would be protected, and consent procedures. Students were informed that participation (or lack thereof) would in no way affect their academic status, grades, or progression within the radiography curriculum. The students that volunteered to participate in the study signed the informed consent form.

An email was sent to those participants that were randomly selected into the experimental pool informing them of the next steps of the study which included:

instructions for accessing the critical thinking module, a deadline for completing the module, the reflective journal document, the identified clinical environments (emergency department, operating room, and/or weekend/evening shift) where the journaling would take place, a timeline for submitting the journals following the clinical rotation, and the procedure for submitting the journals to the researcher. As the intervention took place over the course of the two semesters, the experimental cohort of participants submitted journals to the researcher via email attachment. The submitted journals where then saved on a private, password-protected drive.

All participants completed the CCTST assessments. The assessments were completed online and results were populated into a spreadsheet. The results were made available to the researcher through a private, password-protected access code. Each participant was permitted to see his/her overall individual score, but did not have access to the correct answers for each question.

An addendum to the original IRB application was submitted for approval to add a post-intervention survey targeting the experimental cohort. The researcher determined it was important to capture the impressions, perceptions, and experiences of those closest to the intervention in order to better explain some of the quantitative results. The open-ended survey provided an opportunity for the experimental participants to reflect on the overall effectiveness of the intervention from their viewpoint and to bring meaning to quantitative findings. The follow-up data ultimately enriched the understanding of the phenomenon at hand. An email invitation for participation in the post-intervention survey was sent to the experimental cohort via email. The purpose of the survey, informed consent procedures, and generalization of results was communicated. A timeline and instructions for submitting the survey were provided. See APPENDIX D: POST-INTERVENTION SURVEY for a copy of the survey.

Instrumentation

The California Critical Thinking Skills Test (CCTST) was the quantitative instrument used in the study. As mentioned in the literature review section, the CCTST test has been previously vetted by numerous evidence-based research studies (Domenech & Watkins, 2015; J. Lee et al., 2016; Ross et al., 2016; Tsai, 2014). The test has been used in measuring critical thinking skills for more than 25 years. Over the 25 years, the tool has been vetted through a variety of populations and contexts. The items are piloted in target samples (such as health professionals) and validated in replicated research to confirm the outcome of the assessments in the intended population (Insight Assessment, 2017). The CCTST instrument has been psychometrically assessed in concert with researchers, educators, trainers, and working professionals, in an effort to verify cultural and language competence for the targeted test-taker.

Science offers evidence that higher-order cognitive skills, such as critical thinking, can be evaluated through well-crafted multiple choice items (Fellenz, 2004; Kominski, 2012; Nicol, 2007). The CCTST measures high-stakes reasoning and decision making processes when presented with authentic problem situations formatted through multiple choice answers presented in a range of difficulty and complexity. Each question requires the test-taker to make an accurate and complete interpretation of the problem, and factor in the information presented in order to select the best solution from those provided. The CCTST form used was a 100 point test with higher scores indicating advanced critical thinking ability. The CCTST was calibrated for undergraduate level students in the health sciences discipline.

Content Validity

It is important that the selected test hold the ability to capture a measure of the intended domain (Cronbach, 1990). In the case of the CCTST, the domain of critical thinking is defined by the Delphi consensus. The CCTST has been designed as a holistic measure of the critical thinking construct; therefore, it has embedded scales used to examine the cognitive components of critical thinking such as: *Overall Reasoning Skills, Analysis, Inference, Evaluation, Deduction, Induction, Interpretation, and Explanation.* Table 9 below provides the scale descriptions.

Table 9

Scale Descriptions (adapted from Insight Assessment, 2017)

Scale	Descriptions
Overall Reasoning Skills	Describes overall strength in using reasoning to form reflective judgments about what to believe or what to do
Analysis	Enables the individual to identify assumptions, reasons, and claims and to examine how they interact in the formation of arguments
Inference	Enables the individual to draw conclusions from reasons and evidence
Evaluation	Enables the individual to assess the credibility of sources of information and the claims they make
Deduction	Decision making in precisely defined contexts where rules, operating conditions, core beliefs and procedures completely determine the outcome
Induction	Decision making in contexts of uncertainty, draw inferences about what one thinks is probably true based on analogies, case studies, prior experiences, and patterns
Interpretation	Determines the precise meaning and significance of a message or signal
Explanation	Enables the individual to describe the evidence, reasons, methods, assumption or rationale for decisions, opinions, beliefs, and conclusions

The content validity is further supported by existing research which used the CCTST to study human reasoning skills from educators to scholars to human resource professionals. As mentioned, CCTST questions are structured in the context of everyday situations. All necessary information needed to answer the question accurately is provided in the question stem. The fact that the CCTST measures only critical thinking and not content knowledge affords the opportunity to utilize the instrument in a pre-test/post-test scenario. The pre-test/post-test configuration allows the researcher to evaluate improvement in critical thinking that may occur during an educational intervention (Insight Assessment, 2017).

Construct Validity

Construct validity is often demonstrated through correlational research where critical thinking scores are associated with other measures that aim to include the domain. CCTST is identified as having strong correlations with other tools that aim to measure critical thinking or higher-order reasoning as a component of the ratings or measures (Insight Assessment, 2017). Strong correlation with standardized tests of college-level preparedness in higher-order reasoning have been validated (N. Facione & Facione, 1997).

Construct validity of the CCTST can be evidenced through the improvement in CCTST test scores following a course, educational interventional, or training dedicated to critical thinking. There are peer-reviewed examples of how the CCTST has been utilized to validate improvement in critical thinking skills (Coker, 2010; Kennison, 2006; McCarthy et al., 1999). For the changes in scores to be considered reliable and valid, the changes need to be associated with improvements in critical thinking and not due to any external influences. For the dissertation, as possible, all controllable variables were held constant with the one exception being the educational intervention aimed to increase critical thinking skills. When variables are held constant, one can associate any improved post-test scores with the effects of the intervention aimed to develop critical thinking skills (Insight Assessment, 2017).

Criterion (Predictive) Validity

It is important to know that the CCTST assessment tool can predict a meaningful measure demonstrating achievement of targeted learning outcomes. Scores on the CCTST have been shown to provide predictive value in peer-reviewed independent research (Denial, 2008; Ip et al., 2000; Kennison, 2006; Paans, Sermeus, Nieweg, & Van der Schans, 2010; Sorensen & Yankech, 2008; Williams et al., 2003). Additionally, there is literature supporting the use of the CCTST in examination of learning outcomes (Abrami et al., 2008; Bartlett & Cox, 2002; Brown & Bielinska-Kwapisz, 2015; Eigenauer, 2017; Spelic et al., 2001). The CCTST is also a recognized assessment tool for reasoning skills in US National Science Foundation (NSF) grant-funded research of science education (National Science Foundation, 2005).

Reliability

The measure for internal consistency reliability for the CCTST instrument is the Kuder-Richardson (KR) due to the scoring being dichotomous. KR-20's of .70 are considered to be evidence of strong internal consistency in non-homogeneous assessments. This measure of internal consistency, KR-20 of .70, is the benchmark used for creating the CCTST instrument by the maker, Insight Assessment. The overall score of the CCTST meets or exceed the .70 standard in the validation trials, and in large model population samples. Moreover, the KR statistics for the .70 criterion are commonly witnessed in independent samples when the sample size and variance is sufficient. The range for factor loadings for items is .300 to .770 (Insight Assessment, 2017).

Due to test design, cognitive endurance considerations, and the acknowledgment that Delphi's list of skills are not discrete functions but rather tend to be applied in concert, the questions on the CCTST may or may not be used on more than one scale. Consequently, though the individual skill scores reported on the CCTST satisfy internal consistency reliability, a strong value as indicators of specific strengths and weaknesses, and test-retest reliability, the skills are not independent factors. This is theoretically on target to the holistic conceptualization of critical thinking, which argues the process of reasoned judgment and not simply a list of separate, discrete skills (Insight Assessment, 2017).

According to Insight Assessment (2017), the test/retest reliability for the CCTST instrument meets or exceeds .80 in samples with sufficient variance, retested at two weeks after the pre-test. Further, samples suggest no change after much longer delay than two weeks when no active training in critical thinking has occurred between tests. Insight Assessment (2017) reports that no statistical evidence of an instrument effect has been examined in internal vetting of test retest reliability.

Data Analysis

Research Question One (Quantitative)

Was the chosen educational intervention proven effective as determined by comparing changes in scores on a critical thinking assessment tool between the experimental and control groups?

The research design provided multiple opportunities for quantitative analysis. A demographic analysis was conducted through descriptive statistics to examine the age, gender, and campus location distributions. Descriptive statistics was also used to calculate the mean, median, and standard deviation of scores for the eight scales assessed by the CCTST.

Percentile distribution from aggregate data was analyzed to examine the overall performance level for critical thinking for both the experimental and control groups. The designated aggregate sample of CCTST data selected was health science undergraduates. According to Insight Assessment (2017), the test data was aggregated from randomly selected and weighted subsamples taken from several hundred educational programs from all geographic areas of the country and from all 50 states. While the exact algorithm for the determination of norms is considered property, Insight Assessment (2017) offers that geographic location, size of program, selectivity of program, public/private university, and test-taker demographics are some factors reflected in the algorithm. The norms are considered a powerful tool to assess the relative strength of the test-takers performance in comparison to others in the population (health science undergraduates). The 50th percentile denotes an average performance compared to the national population of test-takers in the designated group. For those scores below the 50th percentile, critical thinking is considered not manifested or weak. For those scores at or near the 50th percentile, the test-takers' critical thinking skills are considered moderate. Test-taker scores above the 50th percentile suggest the critical thinking skills are considered to be strong to superior.

A comparison between minutes spent on the exam versus score was also examined. This data was analyzed to examine how time spent on the exam correlated to the resultant score. As test completion time (in minutes) increased or decreased, the changes in mean score are analyzed.

An independent t-test analysis was conducted to investigate the differences in changes of mean scores between the two separate groups, experimental and control. This test was chosen to analyze the difference in changes of mean scores between the two groups because the groups are considered independent and mutually exclusive of each other. The t-test is used to assess whether the two independent groups are significantly different or if any difference could be due to chance. The null hypothesis suggested there was no significant difference between the experimental and control group. The alternative hypothesis implied there was a significant difference. The standard value for statistical significance is $p < 0.05$. The t-test equation factors in the differences, variability, and sample size of the data set. The independent t-test is considered a powerful, parametric test but is based on certain distributional assumptions that must be met such as the sampling distribution being normally distributed. This is validated when the distribution is symmetrical about the midpoint, the mean, median, and mode are the same, the variable in the distribution is continuous, and the distribution is bell-shaped (Hanna & Dempster, 2012). Even though the sample size for the study is relatively small (N = 20), there are no principal objections to using a t-test for sample sizes as small as two (De Winter, 2013). The independent t-test analysis was conducted through SPSS software (IBM SPSS Statistics, Version 25, 2017).

A histogram of the changes of scores between the pre- and post-CCTST scores for both sets of participants was conducted through SPSS software to evaluate whether or not the symmetrical assumptions were met; and therefore, the independent t-test results could be relied upon. With unsymmetrical distribution, a Mann-Whitney U will be conducted using SPSS software. A Mann-Whitney U is a nonparametric statistic that does not hold stringent assumptions as seen with the independent t-test (Hanna & Dempster, 2012). For the Mann-Whitney U, the dependent variable (change in scores) was continuous, there were categorical independent groups (experimental and control), there is independence of observations (no relationship between observations), and the two variables are not normally distributed. The nonparametric test, Mann-Whitney U, can be used when the sample size is small and the data contain significant variances from normality (Elliott & Woodward, 2007).

According to Insight Assessment (2017), the *Overall Reasoning Skill* scale score is the optimal overall assessment of critical thinking skills when the purpose is to compare individuals or groups of individuals. Therefore this was the scale used to compare the percentile distributions, the minute and score correlation, the independent t-test, and the Mann-Whitney U results.

Research Question Two (Qualitative)

How did the qualitative data generated from the journaling and the participants' post-intervention reflections enhance the overall understanding of the intervention's effectiveness in teaching critical thinking?

The two sources of qualitative data, reflective journals and post-intervention survey, were collected and analyzed for the research study. Both sources of qualitative data were analyzed by first coding the writing or open-ended responses then by identifying common, emergent themes across the individual data sets. During the coding and categorizing process, segments or pieces of the written data were extrapolated from the entire data set and grouped into similar bits of data, which formed categories (Bradley, Curry, & Devers, 2007; Ryan & Bernard, 2003). Codes and emergent categories were designed to capture the written data that would best enrich the understanding of the effectiveness of the intervention. Each written data set was individually coded and specific segments were categorized according to relational context. Research suggests that coding conducted by a single researcher is both sufficient and preferred, particularly when the researcher is uniquely embedded in an ongoing relationship with the participants (Morse, 1994; Morse & Richards, 2002;

Janesick, 2003). The researcher is viewed as the instrument where the collection and analysis are closely interweaved enabling the researcher to “choreograph” his/her “own dance” (Janesick, 2003).

From the codes and categories, a thematic analysis was conducted. The thematic analysis examined the codes generated from the written data to identify recurrent patterns or themes arising from the data (Flick, 2014). The themes were representative of the collective qualitative data set. The coding and thematic analysis was conducted under the premise of capturing the reflections, experiences, and perceptions of the participants to achieve a rich understanding of the intervention’s effectiveness in teaching critical thinking.

In concert with the convergent mixed methods design, the reflective journals were examined for common themes and a collective voice to offer generalizations about the Paul-Elder critical thinking framework as it was applied to real-world clinical situations. The writing and emergent themes from the first semester journals were compared to the second semester journals in order to determine whether the perceptions of participants changed over the course of the intervention. The reflective journal entries were not analyzed for common themes until completion of the intervention.

An additional source of qualitative data analysis was provided through the post-intervention survey. This explanatory design approach yielded qualitative data following completion of the intervention. Post-survey responses to open-ended questions offered qualitative data exploring the usefulness of the framework to teach critical thinking, effectiveness of the reflective journaling activity, changes in defining critical thinking, and explanations for quantitative CCTST results. The textual responses were examined for reoccurring themes among participants to offer an in-depth understanding of the effectiveness of the intervention.

Research Question Three (Mixed Methods Integration)

What conclusions can be made regarding the intervention effectiveness when the two data sets, quantitative and qualitative, merge together?

The very premise of a mixed methods design is to provide a rich, overall understanding of the phenomenon at hand. The in-depth examination of a complex construct, such as critical thinking, is made possible through the integration of both quantitative and qualitative data. Using just quantitative or qualitative data alone would leave a gap in the interpretation of findings and unanswered questions. The intervention design approach with elements of both convergent and explanatory design features optimizes the exploration of data and enriches the ability to compare and contrast the two data sets. The CCTST scores are examined to identify correlation with the qualitative themes generated from the reflective journals. The two data sets are compared to determine the degree of coherence. This integrated analysis, across the data sets, can be generated through a side-by-side joint display (Guetterman, Fetters, & Creswell, 2015).

CHAPTER 4: RESULTS

Introduction

The purpose of the research study was to determine the effectiveness of an educational intervention aimed at teaching critical thinking to imaging science students. The educational intervention involved the administration of an e-learning module detailing a critical thinking framework along with a reflective journaling exercise to facilitate application of the framework following clinical experiences typically associated with critical thinking moments. The study aimed to conclude whether or not the intervention was effective by calculating changes in test scores from a critical thinking assessment tool and examining qualitative reflections from journaling that promoted application of the framework. The quantitative and qualitative data generated from the research will guide educators when seeking to reform curriculum as it relates to critical thinking instructional design and delivery.

The data collected by means of pre-, mid-, and post-CCTST scores, reflective journaling, and a post-intervention survey were analyzed to answer the following research questions that guided this study.

Research Question One (Quantitative): Was the chosen educational intervention proven effective as determined by comparing changes in scores on a critical thinking assessment tool between the experimental and control groups?

Research Question Two (Qualitative): How did the qualitative data generated from the journaling and the participants' post-intervention reflections enhance the overall understanding of the intervention's effectiveness in teaching critical thinking?

Research Question Three (Mixed Methods Integration): What conclusions can be made regarding the effectiveness of the intervention when the two data sets, quantitative and qualitative, merge together?

Demographic Analysis

Of the 20 participants, there were 10 participants in the experimental group and 10 participants in the control group. The majority of the participants (80%) were between the ages of 20 and 23 with the mean age being 21.35 with a standard deviation of 2.73. There were 12 students from the Omaha campus, four students from the Kearney campus, three students from the Grand Island campus, and one student from the Columbus campus. For the 10 participants in the experimental group, the campus distribution was: six from the Omaha campus, two from the Kearney campus, one from the Grand Island campus, and one from the Columbus campus. The distribution of ethnic origin for the 20 students was 5 percent Hispanic/Latino, 10 percent Asian/Pacific Islander, and 85 percent Caucasian. The breakdown of ethnicity for the experimental group was one Asian/Pacific Islander and nine Caucasian. There were three male and 17 female students in the class with one male participant in the experimental cohort. See Table 10 below for a demographic analysis comparing the two groups involved in the study.

Table 10

Comparing Demographics of the Experimental and Control Groups

Group	*N*	*Male (M) vs Female (F) Number*	*Ethnicity Distribution*	*Campus Representation Out of 4 Campuses*	*Mean age*
Experimental	10	1 M:9 F	1 Asian/Pacific Islander 9 Caucasian	4:4	20.8
Control	10	2 M:8 F	1 Asian/Pacific Islander 1 Hispanic/Latino 8 Caucasian	3:4	21.9

Research Question One (Quantitative)

Eight scales were assessed by the CCTST administered. The 8 scales included: *Overall Reasoning Skills, Analysis, Inference, Evaluation, Deduction, Induction, Interpretation, and Explanation.* Table 11 below shows the descriptive statistics for the experimental and control groups generated from the pre, mid, and post-tests.

Table 11

Descriptive Statistics of Scores for the 8 CCTST Scales

CCTST Scale	Experimental			Control		
Test	Pre	Mid	Post	Pre	Mid	Post
N	10			10		
Overall Reasoning Skills						
Mean	77.4	77.3	76.5	72.1	75.3	74.4
Difference Pre to -	XXXXXX	-.1	-.9	XXXXXX	+3.2	+2.3
Median	76.5	78.0	78.5	70.5	77.0	74.0
Difference Pre to -	XXXXXX	+1.5	+2	XXXXXX	+6.5	+3.5
Standard Deviation	4.6	3.6	6.1	3.8	5.9	4.8
Analysis						
Mean	80.5	79.0	73.5	73.0	77.0	75.0
Difference Pre to -	XXXXXX	-1.5	-7	XXXXXX	+4	+2
Median	77.5	80.0	75.0	72.5	80.0	75.0
Difference Pre to -	XXXXXX	+2.5	-2.5	XXXXXX	+7.5	+2.5
Standard Deviation	6.4	3.9	7.8	9.2	7.5	6.7
Inference						
Mean	81.4	79.2	79.2	75.6	76.0	77.9
Difference Pre to -	XXXXXX	-2.2	-2.2	XXXXXX	+.4	+2.3
Median	80.0	80.0	80.0	76.5	78.0	76.5
Difference Pre to -	XXXXXX	0.0	0.0	XXXXXX	+1.5	0.0
Standard Deviation	4.0	3.6	5.1	4.9	6.1	6.5
Evaluation						
Mean	73.3	75.8	75.1	71.6	74.5	72.3
Difference Pre to -	XXXXXX	+2.5	+1.8	XXXXXX	+2.9	+.7
Median	75.0	73.0	77.5	69.0	75.0	75.0
Difference Pre to -	XXXXXX	-2.0	+2.5	XXXXXX	+6	+6
Standard Deviation	8.0	6.8	9.6	7.5	7.7	5.5

Table 11 *continued*

CCTST Scale	Experimental			Control		
Test	Pre	Mid	Post	Pre	Mid	Post
N	10			10		
Deduction						
Mean	76.6	74.3	76.0	70.3	74.6	73.8
Difference Pre to -	XXXXXX	-2.3	-.6	XXXXXX	+4.3	+3.5
Median	77.0	75.5	77.0	69.0	77.0	72.5
Difference Pre to -	XXXXXX	-1.5	0.0	XXXXXX	+8.0	+3.5
Standard Deviation	5.2	4.4	6.8	4.6	5.1	6.3
Induction						
Mean	81.4	83.6	80.8	78.1	79.7	79.0
Difference Pre to -	XXXXXX	+2.2	-.6	XXXXXX	+1.6	+.9
Median	79.0	84.0	82.0	78.0	80.5	79.0
Difference Pre to -	XXXXXX	+5.0	+3.0	XXXXXX	+2.5	+1.0
Standard Deviation	5.3	3.4	6.0	4.1	6.4	3.9
Interpretation						
Mean	81.4	84.7	84.7	78.8	84.0	81.9
Difference Pre to -	XXXXXX	+3.3	+3.3	XXXXXX	+5.2	+3.1
Median	81.0	84.0	84.0	81.0	87.0	87.0
Difference Pre to -	XXXXXX	+3.0	+3.0	XXXXXX	+6.0	+6.0
Standard Deviation	7.8	6.3	6.3	6.1	8.2	8.5
Explanation						
Mean	73.0	76.8	75.5	71.7	72.3	74.2
Difference Pre to -	XXXXXX	+3.8	+2.5	XXXXXX	+.6	+2.5
Median	74.0	74.0	74.0	68.0	74.0	74.0
Difference Pre to -	XXXXXX	0.0	0.0	XXXXXX	+6.0	+6.0
Standard Deviation	8.1	5.5	9.6	8.8	9.7	8.8

Examining the descriptive statistics of the mean values for the experimental group, the following scales resulted in a decrease in score from the pre to the mid as well as from the pre to the post-test: *Overall Reasoning Skills*, *Analysis*, *Inference*, and *Deduction*. There was an increase in score from the pre to the mid as well as from the pre to the post-test for the following scales: *Evaluation*, *Interpretation*, and *Explanation*. The *Induction* scale improved from the pre to the mid-test and decreased from the pre to the post-test. Meanwhile, for the control group, all scales yielded an increase in mean score from the pre to the mid as well as from the pre to the post-test.

Continuing to examine the mean scores, the highest scoring tests and scale for the experimental group was *Interpretation* for both the mid and post-tests at 84.7. The lowest scoring test and scale for the experimental group was the pre-test *Explanation* scale at 73.0. Comparing those results to the control group, the data shows that the highest scoring test and scale for the control group yielded from the mid-test *Interpretation* scale at 84.0. The lowest scoring test and scale for the control group was the pre-test *Deduction* scale at 70.3. Analyzing the highest score for the experimental group (84.7) and the highest score for the control group (84.0), the experimental group's highest score was +.7 higher than the control group. The lowest score for the experimental group (73.0) compared to the lowest score for the control group (70.3) shows that the experimental group's lowest mean score was +2.7 higher than the control group.

Examining the descriptive statistics of the median values for the experimental group, the following scales resulted in a decrease in score from the pre to the mid-test: *Evaluation* and *Deduction*. Additionally, there was a decrease in median score from the pre to the post-test values for the *Analysis* scale. There was an increase in median score from the pre to the post-test for the following scales: *Overall Reasoning Skills, Evaluation, Induction,* and *Interpretation*. Meanwhile, for the control group, all scales yielded an increase in median value from the pre to the post-test with the exception of the *Inference* scale which remained unchanged between the two tests.

Looking at the median scores for the experimental group, the highest scoring tests and scales for the experimental group was *Interpretation* for both the mid and post-tests and the mid-test *Induction* scale resulting in a median score of 84.0. The lowest median score resulted from the *Evaluation* scale, receiving a median score of 73.0. Comparing these median score results from the experimental group to that of the control group, like the experimental group, the *Interpretation* scale yielded the highest median score of 87.0 on the mid and post-test exams. The lowest median score for the control group was found with the *Explanation* scale, resulting in a median score of 68.0. The experimental group's highest median score (84.0) was three points lower than the control group's highest median score (87.0). However, the control group produced the lowest median score between the two groups by a difference of five points (68.0 for the control and 73.0 for the experimental).

The median results are most useful for comparison in this case due to the small sample size and the raw data indicating the presence of outlying scores, which may heavily influence the mean statistic. For example, the mid-test *Evaluation* scale for the experimental group demonstrated two outlying scores for the 10 total scores presented. The lowest score was a 67.0 and the highest score was an 88.0. Four points separated the lowest score to the next closest score received from the group (67.0 to 71.0). Similarly, the highest was an 88.0 and the next highest score yielded from the group was an 84.0, again a four point difference. Given the small number of participants in each group (10), the differences in these score values support giving emphasis to the median statistics.

The reliance on the median statistic over the mean statistic is further validated by examining the raw data from the control group. This data offers another example of how the presence of outlying scores can impact the mean value for the group. For the control group in the post-test *Interpretation* scale, the data shows 68.0 as the lowest score for the group. The next lowest score was 74.0. The highest score received in the group was a 94.0 with the following value set at 87.0. There is a six to seven point difference between the extreme score to the following score (both for the high and low values), supporting the preferential use of the median statistic over the mean given the small number of data points.

The standard deviation, or the extent of variation of scores within a group, is explored to reveal that for the experimental group, the smallest deviation yielded was the mid-test *Induction* scale at 3.4. The largest standard deviation for the experimental group was 9.6 for both the post-test of the *Evaluation* and the *Explanation* scales. The control group generated the smallest standard deviation of 3.8 for the pre-test *Overall Reasoning Skills* scale. The biggest standard deviation of 9.7 was generated for the control group in the mid-test *Explanation* scale.

In addition to the descriptive statistics, the percentile scores for the experimental and control groups were compared to the aggregate sample of CCTST Health Science Undergraduates. Examining the experimental group mean percentile, the test-takers would fall at the moderate to weak performance level for manifesting critical thinking skills as their mean values fall below the 50th percentile. While there are some individual test-takers that demonstrated a higher percentile value, the collective group fell below the 50th percentile mark. Interestingly, one test-taker ranked in the 68th percentile for both the pre and mid-tests and followed with a 6th percentile outcome on the post-test. Overall for the group, the percentile decreased from the pre to the post-assessment by -1.6. See Figure 11 below for the percentile distribution of the experimental group for the pre, mid, and post-assessments.

N	Group Mean			Individual Lowest			Individual Highest		
10	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
	41.4	41.0	39.8	12	17	4	68	68	79

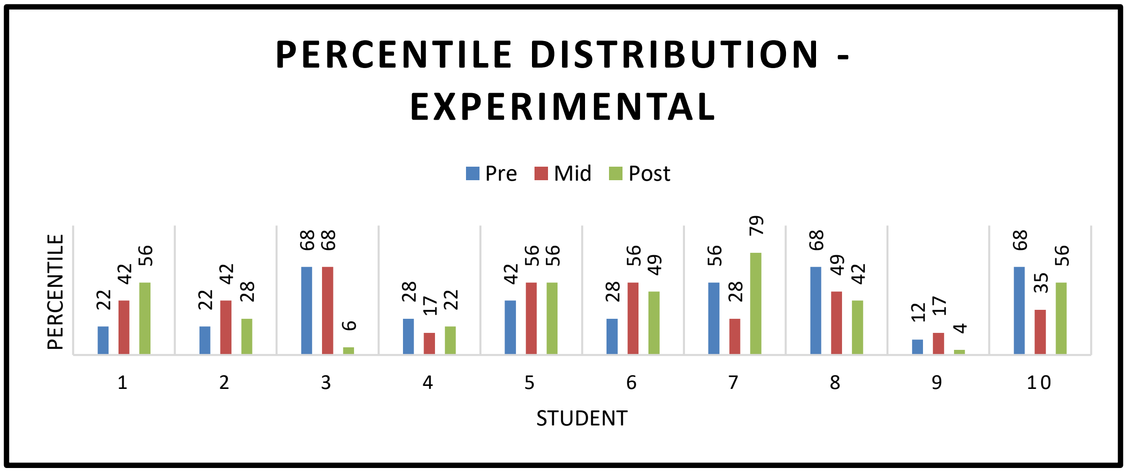


Figure 11. Percentile distribution for the experimental group.

The control group percentile distribution for the pre, mid, and post-assessments is examined in Figure 12 below. Examining the control group mean percentile, the test-takers would fall at the weak to not manifested performance level for revealing critical thinking skills. The percentile increased from the pre to the post-assessment by +9.8.

N	Group Mean			Individual Lowest			Individual Highest		
10	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
	19.5	35.0	29.3	6	1	8	42	62	62

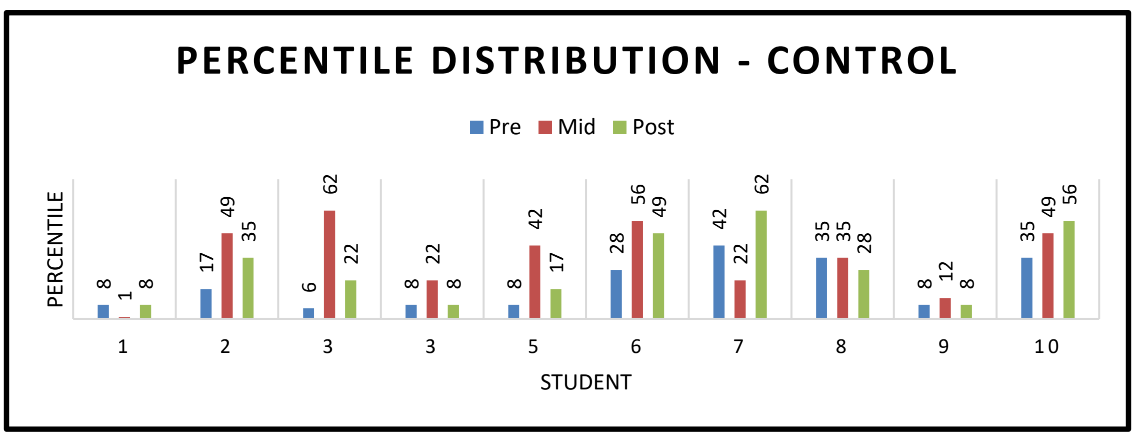


Figure 12. Percentile distribution for the control group.

The experimental group percentile distribution for the pre, mid, and post-assessments can be compared to percentile distribution for the control group. This data is found in Figure 13 below. The overall mean percentile was higher for all three assessments for the experimental group as compared to the control group; however, the control group generated an increase in percentile change from the pre to the post-test, while the experimental group resulted in an overall decrease in percentile change.

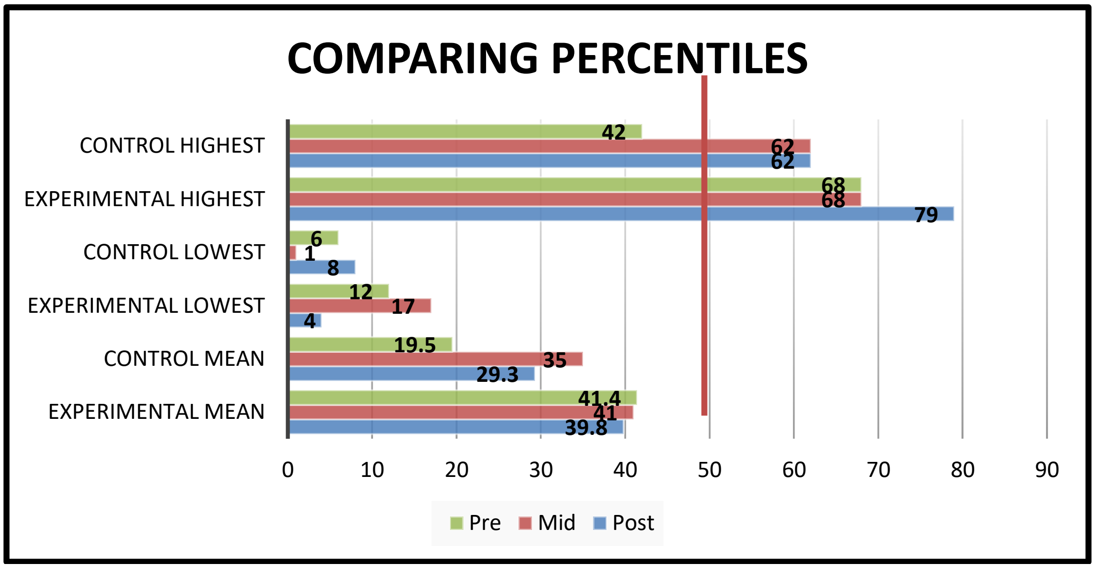


Figure 13. Comparison of percentile data between the experimental and control groups.

Even with the control group's increase in percentile, the performance assessment level remained lower than the experimental group's level. The control group's mean percentile landed at the weak to not manifested performance level, while the experimental group's mean percentile fell into the weak to moderate level for manifestation of critical thinking skills. The control group progressed further in their critical thinking skills according to the percentile changes, but remained deficient in comparison to the experimental group.

Correlation between median time spent on the tests and resultant median scores was reviewed. As mentioned, Insight Assessment (2017) suggests that the *Overall*

Reasoning Skills score is the best measure of critical thinking skills, and therefore, the scale used to evaluate score in relation to time spent on the tests.

For the experimental group, the median time used to complete the test decreased from the pre to the mid-test as well as from the pre to the post-test. Less time was dedicated to answering the questions. Interesting, as the time decreased, the resultant median score for the *Overall Reasoning Skills* scale increased. There was an indirect correlation between time and score. Comparing the pre to the post-test, the experimental group reduced the exam time by approximately seven minutes and demonstrated an increase (2.0) in median score.

For the control group, the median time used to complete the test increased just slightly (approximately 90 seconds) from the pre to the post-test. The control group reduced their exam time from the pre to the mid-test by roughly four minutes. Even though the exam time fluctuated between the three exams, the *Overall Reasoning Skills* scale median scores improved from the pre to the mid-test as well as from the pre to the post-test.

Examining both the experimental and control group's median scores and resultant median time, there are mixed results. The control group appeared to improve their median scores regardless of whether the time increased or decreased; however, the experimental group showed an indirect relationship. As the time decreased, the score improved. See Table 12 below.

Table 12

Correlation between Time Spent on the Exam and Score

CCTST Scale	Experimental			Control		
Test	Pre	Mid	Post	Pre	Mid	Post
N	10			10		
Time (minutes)						
Mean	30.1	29.3	27.1	36.5	36.6	35.9
Median	31.5	28.0	24.0	35.5	31.0	37.0
Difference Pre to -	XXXXXX	-3.5	-7.5	XXXXXX	-4.5	+1.5
Standard Deviation	6.8	7.1	7.9	5.2	19.2	7.3
Overall Reasoning Skills						
Median	76.5	78.0	78.5	70.5	77.0	74.0

An independent t-test analysis was conducted to investigate the differences in change of scores between the two separate groups, experimental and control. According to the SPSS output for the independent t-test, with the significant (Sig.) value (.02) for Levene's Test for Equality of Variances being less than .05, equal variances were not assumed. Therefore, the bottom row of the output was followed when reporting values. The output for the independent t-test indicated there was no significant difference in the change of scores between the experimental and control cohorts (p = .23). See Table 13 below for the SPSS independent t-test output for the change in score generated from the pre-CCTST to the post-CCTST.

Table 13

SPSS Independent T-Test Output for the Experimental vs Control Change in Scores Comparing Pre-CCTST to Post-CCTST

		Levene's Test for Equality of Variances		**t-test for Equality of Means**					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	95% Conf
Score	Equal Variances Assumed	6.99	.02	-1.27	18	.22	-2.80	2.21	-7.45
	Equal Variances Not Assumed			-1.27	11.08	**.23**	-2.80	2.21	-7.67

To help validate the findings calculated from the independent t-test, a histogram was created comparing the change of scores between the two groups to evaluate for symmetry and normal distribution. Figure 14 below is the histogram output from SPSS.

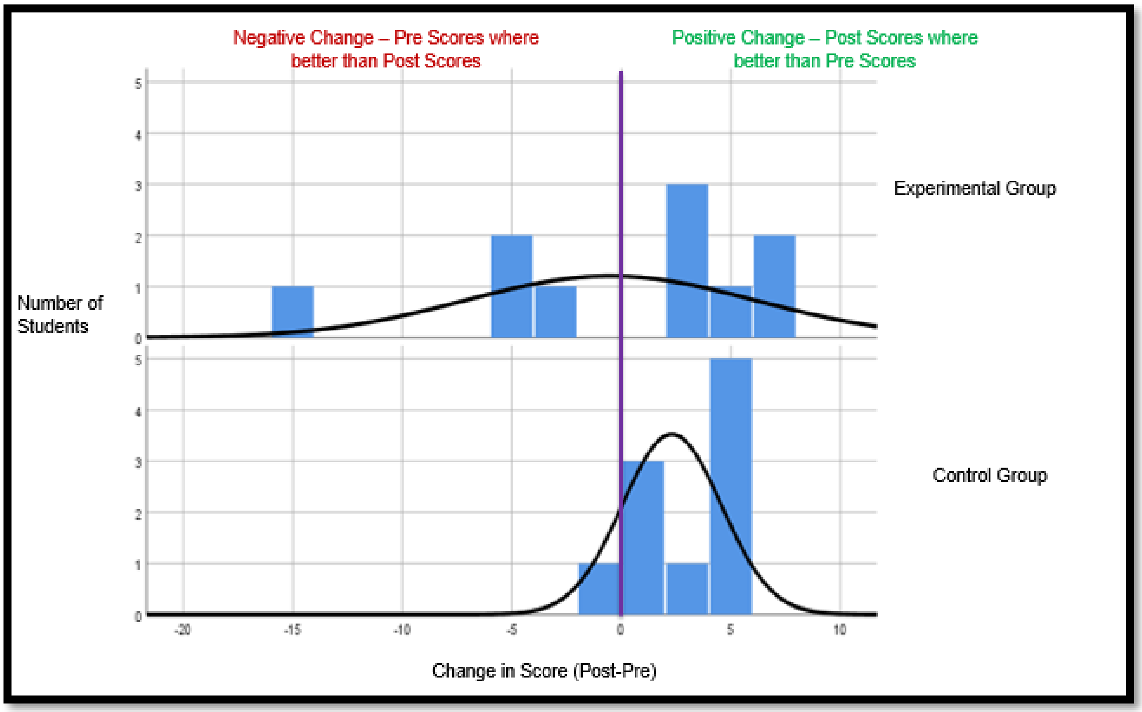


Figure 14. Histogram comparing post to pre changes in score.

Because the two curves resulted in a different bell shape and show no symmetry between the experimental and control data sets, normal distribution is not met as assumed with the independent t-test. This lack of normality coupled with the small sample size suggested the value of performing a Mann-Whitney U statistical test. The Mann-Whitney U further compared the change of scores between the two groups. According to the non-parametric test, there was no significant difference between the experimental and control groups (U = 61, p = .44). See Table 14 below for the SPSS output for the Mann-Whitney statistic.

Table 14

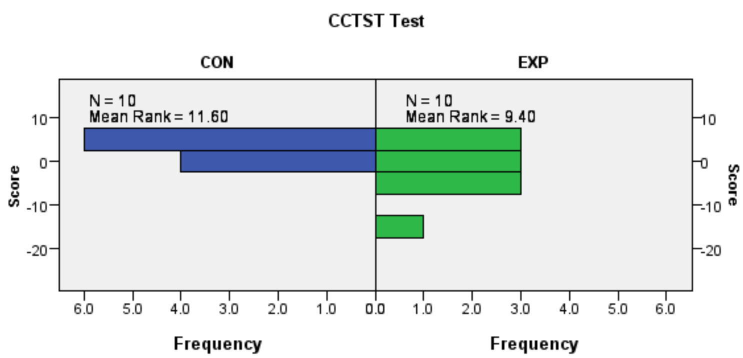
SPSS Mann-Whitney U Output for the Experimental vs Control Change in Scores Comparing Pre-CCTST to Post-CCTST

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Score is the same across categories of CCTST Test.	Independent-Samples Mann-Whitney U Test	.436[1]	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

[1] Exact significance is displayed for this test.



Total N	20
Mann-Whitney U	61.000
Wilcoxon W	116.000
Test Statistic	61.000
Standard Error	13.084
Standardized Test Statistic	.841
Asymptotic Sig. (2-sided test)	.400
Exact Sig. (2-sided test)	.436

Research Question Two (Qualitative)

There were two sources of qualitative data collected and analyzed for the research study, reflective journaling which took place as part of the intervention and the post-intervention questionnaire. Both sources of qualitative data were analyzed by process of coding the responses followed by the development of shared emergent themes across the individual data sets.

The reflective journals, while part of the educational intervention, provided valuable qualitative data in reference to the participant's utilization of the critical thinking framework (See APPENDIX B: REFLECTIVE JOURNAL). The journals, conducted both during the fall and spring semesters, were examined for commonalities and emergent themes among the individual data sets.

Clinical problems where critical thinking was applied were analyzed within the journals. Participants were asked to “Identify a problem or unusual situation that occurred during the clinical experience.” Emergent themes populated from the data set which are reflected in Tables 15 (fall journals) and 16 (spring journals) below.

Table 15

Problem Faced in Clinical Setting: Emergent Themes from Fall Entries

Theme	**Number of Journals Theme Demonstrated in (out of 27 total)**	**Example of Journal Entry**
Patient or Healthcare Professional Issue	9:27	…”the patient woke up from the anesthesia during the surgical procedure.”
Equipment Troubleshooting	7:27	…”the C-arm glitched; it would not move to the lateral position.”
Change in Protocol	6:27	“Since the man was in a tremendous amount of pain, we did not take him to over to an x-ray room, instead brought the portable machine to the ER.”
Difference between Class and Clinic	5:27	“What I learned as a safety factor for the radiologic technologist was not practiced in an exam that took place in the emergency room.”

Table16

Problem Faced in Clinical Setting: Emergent Themes from Spring Entries

Theme	**Number of Journals Theme Demonstrated in (out of 24 total)**	**Example of Journal Entry**
Change in Protocol	16:24	“In the ER we had a patient who came in and required cervical spine x-rays. He was unable to get out of bed and had a neck brace on. We needed an AP, lateral, and AP open mouth view.”
Patient or Healthcare Professional Issue	4:24	“There were several healthcare professionals in the room and some didn’t agree on how to handle certain issues that came up. They started to bicker in front of the patient.”
Equipment Troubleshooting	4:24	“During a surgery today there was a problem with the O-arm and its maneuverability. It took many tries to position the arm in the correct spot.”

Comparing the themes generated from the fall journals to those generated from the spring journals, "patient or healthcare professional issues" was the most prevalent theme in the fall entries while "change in protocol" shifted to the predominant theme in the spring journals. "Difference between class and clinic" was not reflected at all in spring entries.

Both the fall and spring journals revealed overwhelming (78 percent of fall journals and 71 percent of spring journals) support for the Paul-Elder critical thinking framework positively influencing thought processes and decisions along with its effectiveness in reaching an appropriate solution. Participants identified *Purpose* as the most effective "Element of Thought" in terms of developing critical thinking. The least effective "Element of Thought" offered by the Paul-Elder framework in developing critical thinking, as suggested by the participants, was *Assumptions*. The journals offered insight as to why *Purpose* was the most effective and *Assumptions* was the least effective element given the clinical scenario or context in which the participant applied critical thinking. In Table 17 below, there are examples provided from the journals as to why the element was chosen given the context in which the element was selected by the participant.

Table 17

Context and Rationale for Elements Chosen as Most and Least Effective

Most Effective: *Purpose*	
Context: A chest image was ordered on an elderly patient with back pain and inability to move from her bed. Excessive moving could cause further injury.	**Rationale:** "We want to provide each patient with the best care possible while they are in our department. Thinking of this constantly helps me evaluate how I proceed with certain examinations."
Context: While in ER, a non-weight bearing exam was ordered. During lab class, weight bearing protocols are emphasized. Patient could see the student's hesitation, which in turn concerned him. Patient was already scared due to injury and the student's reaction amplified that concern.	**Rationale:** "Our purpose as radiographers is to care for our patients in the most effective way possible. This means making sure they are comfortable and know what is about to happen. We first have to know ourselves what is going on and why."
Least Effective: *Assumptions*	
Context: While in the ER, a hip x-ray was ordered which required raising the unaffected leg. The patient was not able to hold the leg on his own. Students learn to minimize holding during the exposure to reduce the amount of radiation exposure the healthcare professional receives. The patient's spouse was present; however, she did not hold the leg. The radiographer ended up holding the patient's unaffected leg during the exposure.	**Rationale:** "In the moment, I was confident in what I had learned about protecting the radiographer from extra radiation."
Context: While in the ER, patient was admitted after falling off a ladder. Orders were placed for numerous upper extremity images. The patient was in pain so the images where performed using a portable machine rather than in the standard x-ray room. Patient had limited mobility of the arm which required a change in standard positioning protocol.	**Rationale:** "This was the least effective because making assumptions as to how the patient is feeling or how the radiographs were to be obtained did not help the situation. The best way to solve this dilemma was to ask the patient how well he was able to move his arm…"

The post-intervention survey served as the second source of qualitative data (See APPENDIX D: POST-INTERVENTIONSURVEY). Using coding and thematic analysis the following reflections and experiences were revealed. See Table 18 below for the qualitative question, emergent theme, and response examples to support the theme.

Table 18

Question, Theme, and Responses

Question: **How would you define critical thinking?**	
Emergent Theme: **Thinking to solve a problem**	
Response, Example 1: **"Critical thinking, to me, is the ability to think on-the-spot in order to find solutions to problems."**	
Response, Example 2: **"Critical thinking is a way of thinking in which the person uses deep thought and analysis, of things they have already learned, to develop a solution to a problem."**	

Participants were asked if their definition of critical thinking changed after the research project which did not result in a majority consensus but rather mixed reviews. Even with the mixed reviews, the written data showed that the educational intervention made participants aware that: critical thinking can be used in any situation, critical thinking means to dig deeper into the situation, and critical thinking means to analyze the problem and use previous experience to come up with a creative solution.

Participants were asked "What are the key attributes (or characteristics) you would use to describe critical thinking"? Half of the participants identified "open-mindedness" as a key attribute to describe critical thinking. Other attributes or characteristics that emerged from the written data was "introspectiveness" and "interpretation".

The post-intervention survey asked the participant to reflect on the Paul-Elder critical thinking framework and the journaling activity in reference to the teaching or progression of critical thinking. These reflections offer insight as to the overall effectiveness of the educational intervention as viewed by the group so intimately involved in the research. Table 19 shows the reflections for whether or not the Paul-Elder framework was effective in teaching critical thinking. Table 20 shows the responses related to whether or not the student felt the journaling activity progressed his/her critical thinking.

Table 19

Effectiveness of the Paul-Elder Framework to Teach Critical Thinking as Viewed by the Participants

Question: **As you reflect on the Paul-Elder critical thinking framework, do you feel it taught you how to think critically? If yes, why? If no, why not?**
Responses: Yes – 5 No – 5
Yes Response, Example: **"I believe the Paul and Elder critical thinking framework taught me how to think critically because it took me through a number of steps that allowed me to clearly think through each situation I was presented with."**
No Response, Example: **"I feel I was able to think critically before being introduced to the Paul and Elder critical thinking framework but I was unsure of the different elements of thought involved in the framework."**

Table 20

Effectiveness of the Journaling Activity to Progress Critical Thinking as Viewed by the Participants

Question: **As you reflect on the journaling activity, do you feel it progressed your critical thinking? If yes, why? If no, why not?**
Responses: Yes – 8 No – 2
Yes Response, Example: **"Yes, it helped me think through situations more thoroughly from different angles."**
No Response, Example: "**No, I don't think it helped. It was very hard to find situations where critical thinking came up in terms of what the questions were asking."**

The participants were asked to evaluate which portion of the intervention, the framework or the journaling, was most influential in teaching them about critical thinking. The large majority (70 percent) indicated that the Paul-Elder framework was most influential. One of the participants that indicated the framework was most influential commented that "I feel that the framework was the most important thing for my learning. Without knowing the framework and the logistics of critical thinking, reflecting on a situation would have been a lot harder."

An overwhelming majority (90 percent) commented that their critical thinking behaviors had advanced as a result of the educational intervention. One respondent stated:

> The framework has given me ideas about other ways to think about things than I have before. I feel like I can have deeper thoughts or think about things from more angles (where) I wouldn't have before.

Additionally, another participant commented as follows:

> I do feel that my critical thinking behaviors have advanced. Before this research project I do not think that I used much critical thinking at all. Now I find myself using critical thinking multiple times a day. Now it comes to me much more naturally than it used to.

Asking the participants to speculate as to whether or not their CCTST scores improved between the pre, mid, and post-assessment and why, the majority (80 percent) indicated they felt that their scores did improve. The participants offered the following reflections:

> Yes, I feel that my scores improved. They improved because my critical thinking has improved. I also felt that the assessment got easier for me each time because I could use critical thinking to work through each of the problems.

Additionally,

> Yes, my Insight Assessment CCTST scores definitely improved. By learning how to appropriately critically think, I was able to assess the questions asked during this assessment and become confident in what I was thinking. The first time I took this assessment, I was very unsure about my answers and seemed to be guessing in many instances. When it came time to take the post-assessment, I found myself to be much more confident in my thoughts.

A few participants felt that their scores did not improve. Here is an example.

> I was able to do pretty well the first two times, and did worse the last time. I think my critical thinking was already at a pretty good level, and it only

> got better for the second test. The last test I think I rushed too much, and it reflected in my score.

Participants were asked to indicate which of the 7 scales (*Analysis, Interpretation, Inference, Evaluation, Explanation, Induction,* and *Deduction*) on the CCTST assessment tool they felt the strongest and weakest in. *Analysis* was the common response for the perceived strongest scale, while there was no clear consensus for the weakest scale. *Inference*, *Explanation*, and *Interpretation* received equal responses.

Participants were asked to offer their perspectives related to why the experimental group showed an overall decrease in mean score from the pre to the post-assessment for the *Overall Reasoning Skill*s scale, while the control group demonstrated an overall increase in mean score for this scale from the pre to the post-assessment. The emergent theme from the comments was that the experimental group “over-thought” the questions as compared to the control group. Here are some direct quotes from participants which generated the overall theme: “We could’ve taken into account the framework and over-thought everything”, “Maybe the experimental group started to overthink things too much since they had the framework to help them think about things”, and “The subjects in the experimental group were possibly overly focused on the critical thinking needed to answer the questions…”. Basically, the experimental group felt that because they were applying the framework to the scenarios presented in the CCTST questions, ultimately this effort resulted in them allocating too much thought and concentration into each question. According to the reflections, this over-thinking in turn resulted in the experimental group second-guessing the answers which lowered their mean scores.

The survey respondents were informed that the highest scored scale for their group, the experimental group, was *Interpretation*. When asked to speculate as to why this scale resulted in the highest score, a “natural understanding” of the construct was the emergent theme. The comments suggested that because the underpinnings of *Interpretation* hold a more simplistic context, it was easier for students to demonstrate an understanding. When the group commented on why they felt the *Evaluation* scale yielded the lowest score for their group, the emergent theme from the responses was that *Evaluation* represents a “complex” construct. Explanations from the participants suggested that a lot of thought must be applied to this skill from gauging the creditability of sources to factoring in individual judgments and beliefs.

For the bulk of the CCTST scales, the experimental group demonstrated a decrease in mean score from the pre to the post-assessment. The survey participants were asked to explain why these results occurred. Coding the responses and categorizing the codes into themes, the theme of “over-thinking the questions” developed as a generalized explanation for the results. To expand upon this explanation of findings, the participants were prompted to indicate what influence the intervention played or did not play in the decrease in scores. Overall, the participants felt the intervention did influence the score results. Particularly, the intervention prompted “over-thinking” of questions. Comments also suggested that “insufficient time” may have been allocated to answering the questions.

Seventy percent of survey respondents indicated that the Insight CCTST assessment tool was an accurate tool to measure critical thinking. One participant stated that “This assessment takes situations and makes each one of us go into a place in our mind that we don’t normally go. This allows us to better understand and think of solutions.” For the small number of participants (three) that stated the CCTST was not an accurate tool, a common theme from responses as to why was the “insufficient use of applicable scenarios.”

Participants were asked to speculate which of the three CCTST exams they took the most time to complete and explain why that particular exam took the most time. Seventy percent indicated the pre-test resulted in the longest testing time. “Unknown expectations” was the emergent theme as to why the pre-test resulted in the longest time. The participant felt more prepared, both in terms of test structure as well as being equipped with a critical thinking framework, as they completed the mid and post-tests.

A survey question prompted the participants to reflect on whether or not they were a better critical thinker now as compared to prior to the study. If yes, what contributed to that? And if no, why not? All participants responded “Yes”. The primary contributor of the participants being better critical thinkers was the introduction to the Paul-Elder framework.

Research Question Three (Mixed Methods Integration)

The fusion of quantitative and qualitative data promotes a rich understanding of the complex construct, critical thinking. The nature of the convergent and explanatory mixed methods design approaches enables a merging of data for correlation between the two data sets to be analyzed. Joint displays are used to articulate the integrated findings from the two data sets.

For the convergent features of the research, a joint display was developed to compare and contrast the journal entries with the CCTST quantitative scales. The display contained a row for each qualitative domain, or theme, and corresponding quantitative variable with the scale score received for the experimental group. The emergent themes were related to the nature of the problem faced in the clinical setting that prompted critical thinking. The joint display is found in Table 21.

Table 21

Comparison between Qualitative Themes and Quantitative Assessments

Theme	CCTST Scale	Median Score of Experimental Participants
Patient or Healthcare Professional Issues	Analysis	Pre – 77.5 Mid – 80.0 Post – 75.0
Equipment Troubleshooting	Inference	Pre – 80.0 Mid – 80.0 Post – 80.0
Change in Protocol	Evaluation	Pre – 75.0 Mid – 73.0 Post – 77.5
Difference between Class and Clinic (*only applicable to fall journal entries*)	Induction	Pre – 79.0 Mid – 84.0 Post – *Not applicable*

Analysis was the scale used in correlation to the "patient or healthcare professional issue" theme because the *Analysis* description entails gathering information from articles such as charts, spoken language, and documents. When a patient or healthcare professional impacts the flow of procedures or service provided by the imaging science student, the student used critical thinking to collect data and assess the accuracy of the information impacting the outcome. Moreover, the critical thinker identified the elements of the situation and determined how those elements interacted.

Inference was aligned with the theme of "equipment troubleshooting" because conclusions were generated from reason and evidence. When equipment malfunctioned, the student tends to conduct a mental checklist to determine the root cause of the problem. Is the malfunction a human error or truly an equipment issue? What are the known facts and conditions of the situation?

Evaluation corresponded with the "changes in protocol" theme. For this scale, the critical thinker assessed the information and determined the strengths and weakness (benefits or risks) associated with a course of action. When the standard protocol cannot be carried out, the student evaluated how best to proceed by factoring the potential ramifications of the decision. The critical thinker must judge the quality of the modified protocol. How is the patient impacted by the decision? How is the resultant image impacted by the decision?

Induction was the scale interrelated to the “difference between class and clinic” theme. Decisions are made in moments of uncertainty. Critical thinkers rely on inferences about what is likely correct using prior experience as a gauge. Students learn in a controlled environment under ideal situations where standard protocols and best practices are promoted. There can be a detachment or obstacle with the transfer of that knowledge to real-world practice. When the environment becomes real, the student is faced with situations where best practices are not always adhered to; and therefore, drawing on inferences based upon prior experiences can guide the decision making process.

Also reflected in the journals were participant perceptions on which “Element of Thought” was most and least effective. These perceptions are correlated to the CCTST scale most applicable to the element indicated. The joint display showing this correlation between the qualitative and quantitative data sets is found in Table 22 below.

Table 22

Most and Least Effective Element of Thought in Correlation to CCTST Scale

Self-Reported Most and Least Effective “Element of Thought”	**CCTST Scale**	**Median Score of Experimental Participants**
Most Effective: *Purpose*	Interpretation	Pre – 81.0 Mid – 84.0 Post – 84.0
Least Effective: *Assumptions*	Analysis	Pre – 77.5 Mid – 80.0 Post – 75.0

Purpose was perceived as the most effective “Element of Thought” reflected in both the fall and spring journals. *Purpose*, or identifying the main goal or objective, best corresponds to the *Interpretation* CCTST scale because *Interpretation* aims to clarify what something means and categorizes information. *Assumptions* was self-reported as the least effective “Element of Thought” in both the fall and spring journals.

Assumptions, or what is taken for granted, most appropriately aligns with the *Analysis* CCTST scale since it involves the skills related to identifying assumptions and identifying the elements of a situation.

From the explanatory mixed methods design features, the post-survey reflections were used to gain a greater understanding of the CCTST results such as explanations as to why certain results occurred and perceptions related to the overall effectiveness of the intervention. An integrated joint display shows the correlation between the post-survey reflections and the CCTST *Overall Reasoning Skills Scores* (See Table 23).

Table 23

Effectiveness of the Intervention: Perceptions Correlated with CCTST & SPSS

Effectiveness of the Framework	
Question: As you reflect on the Paul-Elder critical thinking framework, do you feel it taught you how to think critically? If yes, why? If no, why not?	
Yes – 5:10	“I believe the Paul and Elder critical thinking framework taught me how to think critically because it took me through a number of steps that allowed me to clearly think through each situation I was presented with.”
No – 5:10	“I feel I was able to think critically before being introduced to the Paul and Elder critical thinking framework but I was unsure of the different elements of thought involved in the framework.”
CCTST Overall Reasoning Median Score: Pre (76.5) Post (78.5) increased from Pre to Post *SPSS Independent T-Test: p = .23, no significant difference between groups* *SPSS Mann-Whitney U: U = 61, p = .44, no significant difference between groups*	
Effectiveness of the Journaling Activity	
Question: As you reflect on the journaling activity, do you feel it progressed your critical thinking? If yes, why? If no, why not?	
Yes – 8:10	“Yes, it helped me think through situations more thoroughly from different angles.”
No – 2:10	“No, I don't think it helped. It was very hard to find situations where critical thinking came up in terms of what the questions were asking. Once I thought of a situation, it was nice to reflect on it and think about how we handled it.”
CCTST Overall Reasoning Median Score: Pre (76.5) Post (78.5) increased from Pre to Post *SPSS Independent T-Test: p = .23, no significant difference between groups* *SPSS Mann-Whitney U: U = 61, p = .44, no significant difference between groups*	
Change in Critical Thinking Behaviors	
In your opinion, have your critical thinking behaviors advanced? If yes, why? If no, why not?	
Yes – 9:10	“Yes, I do feel that my critical thinking behaviors have advanced. Before this research project I do not think that I used much critical thinking. Now I find myself using critical thinking multiple times a day. Now it comes to me much more naturally than it used to.”
No – 1:10	“I wouldn’t say they have advanced in those words. I feel now that I’ve been in different situations that required critical thinking I always stick to the same methods regardless of what’s going on.”
CCTST Overall Reasoning Median Score: Pre (76.5) Post (78.5) increased from Pre to Post *SPSS Independent T-Test: p = .23, no significant difference between groups* *SPSS Mann-Whitney U: U = 61, p = .44, no significant difference between groups*	

CHAPTER 5: DISCUSSION & CONCLUSION

Discussion of Findings

The quantitative results generated from descriptive statistics, the independent t-test, and the Mann-Whitney U provide numeric data used to evaluate of the effectiveness of the education intervention. The qualitative results delivered through reflective journals and the post-intervention survey themes and common threads also permit an exploration of the educational intervention's overall effectiveness as viewed by the participants. The merged, joint displays examine how the findings from the two data sets integrate and correlate. These findings, both in numeric and textual format, present an opportunity to provide rationale or speculations behind the results.

Quantitative Findings Discussion

The quantitative results showed that the experimental group generally received higher median scores on the pre and post-CCTSTs for most of the scales as compared to the control group. However, the experimental group demonstrated progression from the pre to the post-test in the median statistic in four of the eight scales, while the control group improved the median statistic (from the pre to the post-test) in seven of the eight scales. The rationale provided by the experimental group for the quantitative difference in progression on the CCTST tests was that the experimental group simply "over-thought" the questions. This viewpoint is not supported when examining the time to score relationship. Over-thinking questions would suggest an increase in time to complete the exam; however, the experimental group actually allocated less time (varying between 24-31.5 minutes) than the control group (31-37 minutes). It is important to note that while the distribution of the sample into the two groups was randomized, the participants placed in the experimental group ended up being higher academic performers in the program curriculum as compared to the participants in the control group.

The highest performed scale for both the experimental and control groups was *Interpretation*, which is described as determining the precise meaning and significance of a message (Insight Assessment, 2017). This result is not surprising considering the emphasis of interpretive knowledge and skills in both the clinical and didactic settings within the radiography curriculum. Students are taught to ask questions, validate understanding, assess the circumstances, and make determinations based upon facts, experiences, and prior knowledge. With each exam that is ordered, the student interprets the protocol associated with the order, the indication for the exam, and the patient condition. All three of these facets hold meaning and significance in terms of how or if the procedure will be carried out successfully.

The scale that resulted in the lowest median score for the experimental group was *Evaluation* (73.0 mid-test). For the control group, the lowest median score was found in the *Explanation* (68.0 pre-test) scale. The *Evaluation* scale describes the individual's ability to assess the credibility of sources of information. The *Explanation* scale pertains to describing the evidence, reasons, methods, assumption or rationale for decisions, opinions, beliefs, and conclusions (Insight Assessment, 2017). One can speculate that *Evaluation* and *Explanation* are best carried out when the individual has had sufficient time, knowledge acquisition, and prior experiences to rely on when deciphering through critical thinking moments. Given these lowest median scores were populated in the pre and mid-tests, the students may not have had sufficient opportunity to fully manifest the behaviors associated with these two scales.

It is important to note that the lowest mean scores for both groups were generated from the pre-CCTST. Again, these findings are expected due to the student not having manifested many of the decision-making skills nor the ability to articulate rationale for decisions upon matriculation into the curriculum. Defined contexts are still being discovered by the novice student and methods or reasons behind the decisions are yet to be learned. At the time of the pre-CCTST, students were just beginning the professional curriculum; and therefore, had not acquired the knowledge and skill set to work through reality-based situations as effectively as would be expected further along in the curriculum.

The mid-CCTST resulted in the highest (or equal to) median score received for five out of eight scales for the experimental group and eight out of eight scales for the control group. A theory behind the tendency for the mid-CCTST to generate high scores as compared to the pre and post was the timing of the exam and some manifestation of critical thinking resulting from curriculum integration. The mid-CCTST took place upon completion of the first semester of professional curriculum. All participants would have received some didactic and clinical exposure to situations and thought processes promoting critical thinking skills and dispositions. Additionally, the experimental group would have introduced to the Paul-Elder framework and had been completing the journaling activity for approximately three months. A rationale behind the decline (or no change) in score from the mid to the post-CCTST could be the lack of performance incentive. This was a limitation to the study. In future studies, it would be advisable to incentivize students to perform to the best of their ability. Potential methods for motivating students could be to provide a reward for improved results or link the results to a course grade.

Regarding the percentile comparisons of the experimental and control group to that of the CCTST aggregate sample of undergraduate healthcare professionals, one potentially notable consideration is that the students participating in the research were pursing their undergraduate degree and had approximately 50 college semester hours completed at the start of the research study. The two years or roughly 70 college semester hour deficit from the undergraduate aggregate may cause some limitations in terms of comparing the research participants to the CCTST sample. Generally, the participants' performance assessment level landed in the weak range indicating that they did not tend to reach the 50^{th} percentile mark. The few outliers that received above the 50^{th} percentile with performance assessment level of moderate were primarily from the experimental group. This outcome can be expected since the experimental group tended to receive the higher mean scores. For the situations where an individual test-taker performed relatively high on the pre and mid-test (68^{th} percentile) and poor (6^{th} percentile) on the post-test, one may contribute these results to a lack of motivation or absence of an incentive for improved performance.

Examining both the experimental and control group's median scores and resultant median time, yielded varying results. The control group appeared to improve their median scores regardless of the time spent completing the test; however, the experimental group showed an indirect relationship between time and score. As the time decreased, the score improved. There was evidence to suggest a correlation between time spent on the exams and score received. When examining time in comparison to score, the data showed that the exam which took the least amount of time to complete resulted in the highest score. For example, the experimental group received their highest collective median score (78.5) for the *Overall Reasoning Skills* scale on the exam that yielded the shortest completion time (24 minutes). Similarly, the control group demonstrated their highest median score (77.0) with their shortest combined median time (31 minutes). It is not uncommon for students to perform better, at a faster completion rate, on follow-up exams. Students become familiar with the exam structure and ideally some manifestation of critical thinking occurs either naturally or through the intervention to aid the test-taker in “mastering” the exam. Hence the shorter completion time and highest score achieved is not unexpected.

Both the independent t-test and the Mann-Whitney U suggested there was no significant difference between the two groups. While the experimental group tended to receive higher scores, the control group progressed or improved more over the course of the study. These results while notable did not yield a significant difference to quantitatively validate the effectiveness of the educational intervention. If relying on numeric data alone, the findings did not prove the educational intervention to be effective. However, under different research conditions such as increasing the number of test subjects, a significant variance could be realized. Moreover, this is where the value of a mixed methods design is advantageous. If only a quantitative study, there would be questions left unanswered. Numeric trends and results could not be explained by the participants so intimately involved in the intervention.

Qualitative Findings Discussion

The qualitative reflections generated themes and common threads related to problems faced in the clinical setting that prompted critical thinking, perspectives on the effectiveness of the Paul-Elder framework and the journaling activity, as well as the progression of critical thinking behaviors. The clinical problems faced by the students were real, thought-provoking situations that allowed the student to apply the skills and affective dispositions associated with critical thinking. The journaling forced the students to reflect, analyze, and deliberately think through a complex scenario they faced. The prompted questions of the journal guided the students through the Paul-Elder framework as to model how decisions are made in real situations. The themes generated from the clinical problem reflections represent common dilemmas faced in practice. There was one theme in the fall journals that did not appear in the spring journals, “difference between class and clinic”. This is congruent with transitioning from a novice student to a more seasoned student. Initially when starting a professional curriculum, the student’s expectation is for the didactic setting to match the clinical setting. Students quickly adapt to the reality that rarely are there “textbook” scenarios. Critical thinking is vital to transferring knowledge and skill from the controlled didactic environment to that of the unpredictable world of real practice. Because this theme was not indicated in the spring journals suggests that students learned to anticipate thinking outside the box.

The journal reflections were insightful in suggesting the most and least effective “Element of Thought”. *Purpose* was communicated as the most effective element while *Assumptions* was the least effective element. Applying these reflections to the professional curriculum and experiences as a student in the program, these findings are congruent and expected. The element of *Purpose* denotes the goals and objectives for reasoning (Paul & Elder, 2006). This approach is enriched early within the curriculum. When performing radiographic procedures, imaging professionals are educated and trained to first establish the desired outcome of the exam. The measure of a successful outcome hinges upon the set goal and whether or not it was achieved.

Assumptions being the declared least effective element is also in alignment with the professional curriculum and reflective of common student experiences in the radiography program. Paul and Elder (2006) described the element as identifying assumptions and determining if they are justifiable. Performing imaging procedures requires an open mindset, one without preconceived assumptions as key factors potentially influencing the outcome can be missed if the operator is focused on his/her own point of view. Imaging professionals are trained to address each new procedure without assumptions. An erect chest order with an unstable patient is not feasible. The professional knows that despite the order requesting an erect image, he/she cannot assume it is feasible until a thorough examination of the patient's physical and cognitive ability is assessed.

Integrated Findings Discussion

Examining the joint displays where the quantitative and qualitative data sets merge and integrate, it is evident that while the statistical data did not suggest a significant difference between the experimental and control groups, there is an overwhelming indication that the educational intervention was deemed beneficial as offered through the qualitative reflections and explanations. The participants felt that despite the quantitative test results, their critical thinking behaviors did change. Their perceived acquisition of critical thinking knowledge benefited from an activity such as the reflective journaling to practice the application of critical thinking. The views of the participants indicated that the journaling activity structured by a framework did prompt critical thinking thought processes.

Correlation to Previous Research

Linking the findings of this research to that of existing research, there are both correlations and implications to examine. As found in the literature, there is vast research regarding the educational strategies used to teach critical thinking. However there remained an ever-present gap regarding the effectiveness of these strategies in the field of imaging science. Following this research, some of the gaps are now filled.

Defining Critical Thinking

Literature offered a multitude of definitions for critical thinking from leading researchers such as Watson and Glaser, Paul and Elder, Brookfield, and Ennis. The definition generated from the Delphi consensus project has proven to be a gold standard description of critical thinking, and one that is utilized time and time again in prominent research studies. There is a direct correlation between this established definition of critical thinking and that offered by the participants in this study. The participants described critical thinking as “thinking to solve a problem”. The Delphi definition describes critical thinking as being purposeful judgment yielded from various thought processes. When the participants refer to “thinking”, they are in essence indicating that there is a deliberate or “purposeful” process taking place. Moreover, “…solving a problem” is correlated with a “judgment”. The participant’s definition reinforced that offered by the Delphi consensus project. This finding can support the use of the Delphi definition in the field of imaging science.

Teaching Strategies for Critical Thinking

As suggested by Huang, Newman, and Schwartzstein (2014) and Sharples et al. (2017), the value of deliberately incorporating critical thinking content into a curriculum is evident in the research. Participants offered a plethora of clinical experiences in which to apply the Paul-Elder framework. Congruent with the findings of Bartlett and Cox (2002), currently the radiography program relies on the acquisition of critical thinking knowledge to be enriched by clinical experiences. Until the educational intervention employed by this research study, the only educational strategies used to promote the development of critical thinking was clinical experiences and higher-order thinking didactic exercises.

The literature stated that the most effective strategies to teach critical thinking are those that offer active learning components, where the student is learning by doing (Freeman et al., 2014, J. Lee et al., 2016). Following the existing literature on the effectiveness of reflective writing as a proven strategy for explicitly teaching critical thinking, the educational intervention used in this research incorporated a reflective journaling activity. This activity allowed the participants to learn by doing. They took a clinical experience and applied a framework using prompted or guided reflective questions. The real-world application of working through a problem in methodical way ranked favorably with the participants in terms of critical thinking acquisition. This research finding serves to advance the current deficit in literature related to the benefits of reflective journaling in the field of imaging science as perceived by the end-user. Not only does the implication of reflective journaling, as a productive learning strategy, fill a gap in literature, the journal document itself offers a concrete example of how to structure a reflective writing assignment aimed at facilitating the development of critical thinking. These findings will move the profession of imaging science toward necessary curriculum revision where more deliberate teaching of critical thinking occurs. It will provide a pathway with an established reflective journal structured by a framework.

Assessment of Critical Thinking

Regarding the assessment tool used to quantitatively measure critical thinking, the CCTST, the participants supported the existing literature validating its use in measuring critical thinking skills (Domenech & Watkins, 2015; J. Lee et al., 2016; D. Ross et al., 2016; Tsai, 2014). The framing of the CCTST questions into situations requiring in-depth thought was of particular value according to participants. Using the CCTST to measure critical thinking of imaging science students is not currently established in literature. The research study will contribute to the body of knowledge in the profession related to the assessment of critical thinking. Even with the supportive viewpoints from participants regarding the effectiveness of the CCTST, there were some notable considerations which may be construed as limitations.

Limitations

It is important to recognize any limitations to the research study so that as future research projects are proposed considerations are made to minimize limitations. Learning from previous research is foundational to the ongoing advancement of science. There were a few key limitations presented in the research study.

Inherent Research Considerations

With any research involving human subjects, there is a possibility of the Hawthorne effect to come in play. The Hawthorne effect is a phenomenon where subjects change their behavior simply because they know they are being studied (McCambridge, Witton, & Elbourne, 2014). Applying this phenomenon to the study's results, it is possible, though not substantiated, that the effect led to biases altering the study outcomes. While the experimental group reported favorably that the intervention was effective from their perspective, the quantitative data suggested otherwise. It is possible that the experimental group could have possessed some degree of bias in perceiving the intervention as effective given their awareness of being the subject group studied, time spent on completing the intervention, and motivation to gratify or meet the expectations of the researcher. While possible, it is not likely to have had a significant influence on the overall findings of the research. To minimize the potential impact of the Hawthorne effect in future studies, a more robust sample size could be utilized, the primary researcher could be disassociated from the study group (not so intimately connected), the participants could be blinded as to what group they were randomized into (experimental or control), and careful selection of a research design such as mixed methods could be used to minimize the potential of the built-in biases.

Another inherent consideration when conducting research involving human subjects, especially within a small, well-connected research group, is the potential for contamination between the two cohorts. The study aimed to minimize the possibility of contamination by designing the components of the intervention to be completed outside of the learning environment where most interaction between the two groups would take place. For example, the first phase of the educational intervention was the online learning module with password protected log-in access. The experimental group completed the module on their own time, in an environment external to the program setting. The second phase of the intervention, the reflective journaling, was also conducted outside of the structured learning environment. While the clinical experiences that prompted critical thinking and application of the framework occurred within the program structure, the actual journaling activity was removed from the learning environment where contamination could have occurred.

Subject Number

As a pilot study with a total of subject number of 20, 10 in the experimental group and 10 in the control group, findings are difficult to generalize across the spectrum of all radiography students. This pilot study used convenience sampling strategies to recruit subjects for participation. Convenience sampling was utilized due to the accessibility of participants to the researcher as the program director of the radiography program. This unique relationship coupled with the overwhelming gap in literature related to educational interventions aimed to teach critical thinking to imaging science students made the research valuable and impactful to the field of science despite the sample size. The participants were able offer insightful data both quantitatively and qualitatively that will fill gaps in literature. Equally as importance, this data will serve as a foundation for future, more robust sample size studies. Qualitative research suggests that there is value in collecting data from even one individual. The small sample size is additionally supported by the design methodology employed in the study. Using a mixed methods approach to analyze the research questions posed in the study, helped to minimize any negative effects caused by the sample size number. Where the impact from the small sample size may be felt in the quantitative data set, the qualitative reflections lessened the influence. In the end, there is much to be gained from the findings as many radiography programs have similar enrollment numbers and can make comparisons as a result.

Aggregate Comparison

Another potential limitation observed in the research study was that of the aggregate sample used to compare CCTST data. The aggregate sample was Health Science Undergraduates (4-year colleges and universities). It is possible that a more comparable sample could have been the Technical and Community College norm (2-year college). Many of the program’s students enroll in the professional radiography curriculum with approximately 50 college prerequisite hours (or roughly two years of post-secondary education). The foundation of knowledge resulting from 50 hours may be more closely associated to the 2-year Technical and Community College aggregate than the 4-year Health Sciences Undergraduates group. While this determination could be debated, it did not influence the scores generated. This comparison only impacted the percentile of comparison where the participants were shown as demonstrating at the “not manifested” to “moderate” performance level. If the aggregate sample was adjusted to the Technical and Community College group, the participants’ scores could have landed at a different performance level.

Performance Incentive

The final limitation recognized in the study was the lack of performance incentive offered to the participants when taking the CCTST exams. Participants showed that they may not have been intrinsically motivated to perform well or apply effort in thoroughly completing the CCTST exams, especially towards the end of the study. Looking at the individual raw data, there is some evidence of a change in performance over the course of the study even though a paired t-test analysis did not indicate a significant difference between exams for the individual test-taker. For example, one participant received a 83.0 mean score for the *Overall Reasoning Skills* scale on the pre-test, an 83.0 mean score on the mid-test, and a 68.0 mean score on the post-test. Another subject received an 83.0 mean score on the pre-test, a 79.0 on the mid-test, and concluded the study with a 78.0 on the final CCTST. For the majority of scales, the highest mean scores were received during the mid-CCTST followed by a decline in score during the post-CCTST even though the participants would have had more time to manifest critical thinking skills, both naturally and facilitated by the educational intervention. If the participants took the CCTST exams in a more high-stakes scenario with an academic ramification associated with the results or a reward for improved performance, it is theorized that different scores may have resulted. It should not be assumed that participants will be intrinsically motivated to perform well. With an incentive offered to the participants, there could have been more investment in the outcome.

Implications and Future Research

Despite quantitative results suggesting there was no significant difference between the experimental and control groups, and despite the CCTST mean scores demonstrating a decline in outcome for the experimental group there is still significance in the science that was conducted. The implications the research has on the field of imaging science is profound. It offers science and data where there was none. It offers guidance for future research studies. It offers clarity for how the profession defines critical thinking and a tool that can be used to measure it. It offers evidence related to the effectiveness of a teaching strategy for critical thinking. Additionally, it offers a reflective journal document which programs can integrate into their curriculum so that a more deliberate effort in teaching critical thinking can be realized. All in all, the findings generated by the research suggest that the science generated within the field of imaging science profession may not be far off from other healthcare professions. By that, the results of the study imply that there is a strong probability that the findings generated by other healthcare disciplines may be transferred to the field of imaging science. The study showed the definition of critical thinking, the tool used to measure critical thinking, and the teaching strategy used to foster the development of critical thinking can be shared among many healthcare disciplines. While the data generated from the research study combined with the existing literature offers many valuable implications for the science behind critical thinking, the complexity of critical thinking lends itself to many years of continued research.

As research uncovers answers to questions, new questions ultimately form. Science is ongoing and there is much yet to learn about critical thinking. Examining the data generated from the study, considerations for future research may involve adding numbers to the data set. Given the small sample size used in the study, it may be advantageous to collaborate with multiple radiography programs. Pooling the student data, both the CCTST scores and the journal writing, more generalized findings could be applied across all radiography programs. Should the research project be replicated with multiple programs participating, it is recommended that performance be incentivized. Offering incentives for performance outcomes will make the participants more invested in the results.

Another recommendation for future research would be to replicate the study with the addition of the California Critical Thinking Disposition Inventory (CCTDI). The CCTDI is an assessment that can be taken in conjunction with the CCTST. The CCTDI aims to measure the disposition to engage problems and make decisions (Insight Assessment, 2017). Given the definition of critical thinking describes both cognitive skills and affective dispositions, it would be valuable to collect and analyze data from both assessments and compare. As mentioned in the literature review section, the science behind the relationship of critical thinking skills and dispositions remains deficient. Researchers have yet to show empirical evidence as to how the two components interweave.

A final recommendation for future research would be to examine how programs can effectively integrate critical thinking into the curriculum through a deliberate approach. Healthcare educators have openly stated the significance of teaching critical thinking, yet there remains an opportunity to demonstrate how curricula can be reformed to integrate the content in a meaningful and effective way. Literature implies that an active learning instructional design approach is optimal but proven examples with demonstrated positive outcomes would advance science. Given this study's results suggesting the effectiveness of the reflective journaling activity as viewed by the participants, coupled with previous literature validating the use of journaling for the advancement of critical thinking, guided journaling may serve as a starting point for integrating more a deliberate critical thinking component into a curriculum.

Conclusion

From the existing literature, various definitions, frameworks, and learning strategies for critical thinking are offered. The commonly used definition for critical thinking generated from the Delphi consensus project guided this research. The Delphi definition for critical thinking was interwoven into the chosen Paul-Elder framework. The application of the framework prompted through reflective journaling, a research-supported strategy for developing critical thinking, served as the educational intervention aimed to deliberately teach critical thinking to radiography students. The effectiveness of the educational intervention was examined through quantitative changes in test scores and qualitative reflections through journal entries and a post-intervention survey. The merging of the two data sets offered through an intervention mixed methods design enabled a rich understanding of the complex phenomenon, critical thinking.

The key findings from this research suggested that the field of imaging science: supports the definition of critical thinking as generated by the Delphi project, can utilize the Paul-Elder framework to guide educational strategies, and supports through qualitative data that the reflective journaling activity is beneficial in teaching critical thinking. In response to changing workforce demands and educational initiatives set forth by accreditation standards and professional codes of ethics, radiography programs can use this research to advance curriculum reform by deliberately incorporating a learning activity aimed to teach critical thinking. Resulting from this research, reflective journaling is a promising start to accomplishing this mission. This research provided a journaling document with guided prompts to apply the Paul-Elder framework, which is currently absent in the imaging science field. Educators, regardless of discipline, hold value in students learning the cognitive skills and affective dispositions which define critical thinking. The next step is to incorporate the learning strategies for deliberate teaching of critical thinking. The constantly evolving work environment and numerous stakeholders demand it.

The complex nature of critical thinking lends itself to ongoing research. Opportunities to advance the overall understanding and optimization of critical thinking in practice continue to exist. To stop researching critical thinking is to stop thinking, to stop asking questions, and to be closed to alterative perspectives; all which go against the core tenets of critical thinking. Critical thinking has no end; rather, it represents an ongoing effort to explore, to understand, to grow, and to learn.

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APPENDIX A: CURRENT PRACTICES SURVEY

University of Nebraska Medical Center

Survey Purpose: The purpose of this survey is to determine the current practices employed by Radiography programs to promote critical thinking behaviors in students.

Survey Questions:

1) What is the terminal educational level associated with completion of the Radiography curriculum at your institution?
    a. Certificate
    b. Associates Degree
    c. Bachelor Degree
2) What is the average class size of students that matriculate into your Radiography program per year?
    a. 0-10
    b. 11-20
    c. 21+
3) What is the number of prerequisite hours required prior to matriculation into your Radiography Program?
    a. 0 – there are no prerequisite hours required
    b. 1-15
    c. 16-30
    d. 31+
4) Which option best describes the structure of your Radiography curriculum?
    a. Didactic (classroom) and clinical performed congruently
    b. Didactic (classroom) prior to clinical placement
5) What is your Program's stance on job shadowing experiences prior to matriculation into your Radiography program?
    a. Job shadowing experiences are required
    b. Job shadowing experiences are encouraged, but not required
    c. We have no stance on job shadowing experiences
6) Within your Program's curriculum, how soon do your students enter the clinical environment where they are assisting in patient care (non-simulated)?
    a. Within the first month of matriculation
    b. After the first month, but within the first three months of matriculation
    c. After the first three months, but within the first six months of matriculation
    d. After the first six months, but within the first year
    e. After the first year of didactic coursework is complete
7) Within your Program's curriculum, how soon are your students placed into Emergency Room (ER) or Operating Room (OR/Surgery) clinical rotations?
    a. Within the first month
    b. After the first month, but within the first three months
    c. After the first three months, but within the first six months
    d. After the first six months, but within the first year
    e. After the first year of didactic coursework is complete

8) Is there a specific Critical Thinking framework (ie, Paul-Elder) that is taught to your students as part of your Radiography curriculum?
    a. Yes →Please answer question #9
    b. No → Skip to Question #10
9) If you answered "Yes" to question #8, please tell us the specific Critical Thinking framework that you use. (open-ended)
10) Do you feel there is value in teaching a Critical Thinking framework to your Radiography students?
    a. Yes
    b. No
11) Based upon your response to the previous question, please tell us why you feel that there is or is not value in teaching a Critical Thinking framework to your Radiography students. (open-ended)
12) From which of these avenues do you believe students will gain the most critical thinking behaviors? (check all that apply/how important…rank in order of importance)
    a. Didactic (Classroom) Instruction
    b. Clinical Experiences
    c. Learning activities such as Case Study Analysis, Journaling
    d. Knowledge of a Critical Thinking Framework
13) Does your Program educational activities aimed specifically at promoting critical thinking behaviors?
    a. Yes →Please answer question #14
    b. No → Skip to Question #15
14) If you answered "Yes" to question #13, please indicate which of the following educational activities are offered by your program. (check all that apply)
    a. Reflective journaling
    b. Higher-order thinking learning objectives
    c. Problem-based learning /Case study analysis
    d. Other, please indicate
15) How would you describe the level of critical thinking behavior of your first-year (junior) students versus your second-year (senior) students?
    a. Juniors are not as advanced as the seniors
    b. Juniors are just as advanced as the seniors
    c. Juniors are more advanced than the seniors
16) Does your program assess critical thinking as a student learning outcome?
    a. Yes →Please proceed to question #17
    b. No → Skip to Question #19
17) If you answered yes to question #16, please indicate how the critical thinking student learning outcome of "Students will adapt standard procedures for non-routine patients" is measured. If you answered no to question #16, please advance to question #19. (check all that apply)
    a. Professional/Affective evaluation
    b. Competency evaluation, any exam
    c. Competency evaluation, a specific exam such as "Pediatric, 6 years or less" or "Trauma Lower Extremity"
    d. Other, please indicate
18) If you answered yes to question #16, please indicate how the critical thinking student learning outcome of "Students will critique images to determine diagnostic quality" is measured. (check all that apply)

   a. Professional/Affective evaluation
   b. Competency evaluation
   c. Didactic (classroom) course assignment
   d. Other, please indicate

19) Does your institution utilize a pre-matriculation critical thinking assessment tool during the admission process?
    a. Yes
    b. No
20) If you answered yes to question #19, please indicate which critical thinking assessment tool. (open-ended)

Thank you for your participation in this research project! Your feedback is very valuable and greatly appreciated!

APPENDIX B: REFLECTIVE JOURNAL

University of Nebraska Medical Center

RESEARCH STUDY:
PI: TAMMY JONES

REFLECTIVE JOURNAL

CLINICAL ROTATION AREA (OR/Surgery, ER/Trauma, Evening/Weekend): ________________

DATE OF ROTATION WEEK: _________________

INSTRUCTIONS:

- PLEASE PROVIDE A DETAILED RESPONSE FOR EACH PROMPTED STATEMENT BELOW AS YOU REFLECT ON CLINICAL EXPERIENCES.
- PLEASE SUBMIT THE COMPLETED JOURNAL TO THE PRINCIPAL INVESTIGATOR OF THE STUDY UPON COMPLETION OF THE CLINICAL EXPERIENCE, TO tljones@unmc.edu.

REFLECTION PROMPTS – *ELEMENTS OF THOUGHT*:

1. *Purpose:* Identify the purpose or objective of the clinical experience in the indicated rotation area. Identify what you are aiming to accomplish during the rotation.

2. *Question at Issue:* Identify a problem or unusual situation that occurred during the clinical experience. Identify the underlying questions that arise from the problem.

3. *Information:* Document what you observed and experienced, or any facts related to this clinical situation. Identify any missing information that would aid in an effective resolution to the problem.

4. *Interpretation & Inference:* Identify all possible resolution(s) to the problem. Determine whether the ideal resolution is logical considering the information known about the situation.

5. *Concepts:* Identify key concepts, theories, or principles that assist in fully understanding the issues at hand relevant to the problem.

6. *Assumptions:* Identify any factors, preconceived expectations, or notions that may be assumed or taken for granted.

7. *Implications & Consequences:* Identify the consequences (pros and cons) associated with the potential resolutions to the problem. Identify if one resolution is more favorable than another based upon the implications associated with each.

8. *Point of View:* Identify any perspective or frame of reference that may not have been taken into account, which could be relevant to understanding the problem at hand more thoroughly. Consider if there is another way of looking at the problem.

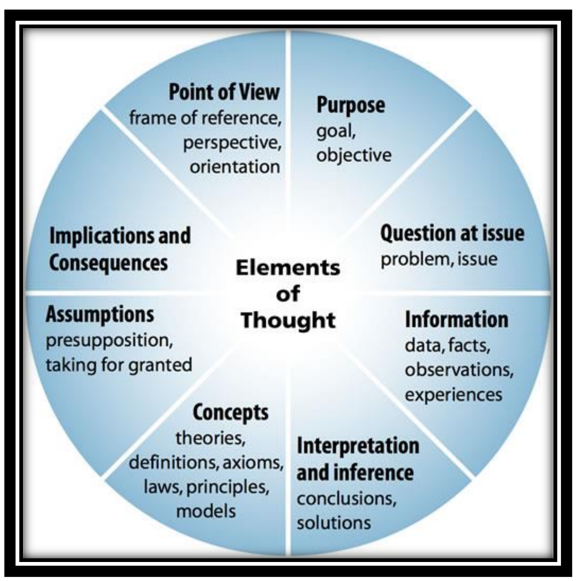
REFLECTION PROMPTS – *EVALUATION OF MODEL*:

9. As you reflect on the clinical experience, how did being familiar with the Paul-Elder Critical Thinking Model influence your thought process and decision-making?

10. When applying the Paul-Elder Critical Thinking Model to your real-world clinical problem, how effective do you feel the model was in resulting in an effective solution?

11. Which "Elements of Thought" offered by the Paul-Elder Critical Thinking Model were most effective in developing your critical thinking? And why?

12. Which "Elements of Thought" offered by the Paul-Elder Critical Thinking Model were least effective in developing your critical thinking? And why?



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APPENDIX C: IRB APPROVAL

University of Nebraska Medical Center

NEBRASKA'S HEALTH SCIENCE CENTER

Office of Regulatory Affairs (ORA)
Institutional Review Board (IRB)

August 21, 2015

Tammy Jones, MPA RT(R)(M)
Radiation Science Technology Div
UNMC - 4545

IRB # 607-15-EX

TITLE OF PROPOSAL: Progression of Critical Thinking among Radiography Students

The Office of Regulatory Affairs (ORA) has reviewed your application for *Exempt Educational, Behavioral, and Social Science Research* on the above-titled research project. According to the information provided, this project is exempt under 45 CFR 46:101b, category *1 and 2*. You are therefore authorized to begin the research.

It is understood this project will be conducted in full accordance with all applicable HRPP Policies. It is also understood that the ORA will be immediately notified of any proposed changes for your research project.

Please be advised that this research has a maximum **approval period of 5 years** from the original date of approval and release. If this study continues beyond the five year approval period, the project must be resubmitted in order to maintain an active approval status.

Sincerely,

Signed on: 2015-08-21 15:58:00.000

Gail Kotulak, BS, CIP
IRB Administrator III
Office of Regulatory Affairs

University of Nebraska Medical Center
NEBRASKA'S HEALTH SCIENCE CENTER

Office of Regulatory Affairs (ORA)
Institutional Review Board (IRB)

September 29, 2016

Tammy Webster, MPA RT(R)(M)
Radiation Science Technology Div
UNMC - 4545

IRB # 607-15-EX

TITLE OF PROPOSAL: Progression of Critical Thinking among Radiography Students

RE: Request for Change, dated *09/22/2016*

DATE OF REVIEW: *09/29/2016*

Dear Ms. Webster

The UNMC ORA has completed its review of the above mentioned Request for Change involving adding a follow-up survey with email correspondence.

This letter constitutes official notification of approval of the revised application and a new survey and email.

You are authorized to implement this change accordingly.

Respectfully Submitted,

Signed on: 2016-09-29 10:39:00.000

Gail Kotulak, BS, CIP
IRB Administrator III
Office of Regulatory Affairs

APPENDIX D: POST-INTERVENTION SURVEY

UNMC
BREAKTHROUGHS FOR LIFE.

RE: 607-15-EX
Post-Intervention Survey

How would you define critical thinking?

Has your definition of critical thinking changed after the research project? If so, how? If not, why not?

What are the key attributes (or characteristics) you would use to describe critical thinking?

As you reflect on the Paul and Elder critical thinking framework, do you feel it taught you how to think critically? If yes, why? If no, why not?

As you reflect on the journaling activity, do you feel it progressed your critically thinking? If yes, why? If no, why not?

Which portion of the intervention, the framework or the reflective journaling, do you feel was most influential in teaching you about critical thinking?

In your opinion, have your critical thinking behaviors advanced? If yes, why? If no, why not?

Do you feel your Insight Assessment CCTST (critical thinking test) scores improved between the pre, mid, and the post-assessment? If yes, why? If no, why not?

Is there a category (Analysis, Interpretation, Inference, Evaluation, Explanation, Induction, Deduction) on the Insight Assessment CCTST which you felt you were strongest in? Why did you feel strongest in this category? In your perception, did your "strongest" category change between the pre and post exams? If so, to what category did it change and why do you anticipate it changed?

APPENDIX E: COPYRIGHT PERMISSION

Figure 1. An Integrated Critical Thinking Framework (Dwyer et al., 2014)

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Figure 2. 5-Step Model to Move Students toward Critical Thinking (Duron et al., 2006).

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Figure 3. Paul-Elder Critical Thinking Framework and Figure 4. Elements of Thought (Paul & Elder, 2006).

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Signed: Tammy Webster   10/30/17

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