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Effect of the Scientific Method Model of Instruction in Diagnostic Medical Sonography Students

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Concordia University–Portland

College of Education

Doctorate of Education Program

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Effect of the Scientific Method Model of Instruction
in Diagnostic Medical Sonography Students

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Concordia University–Portland

College of Education

Dissertation submitted to the Faculty of the College of Education

in partial fulfillment of the requirements for the degree of

Doctor of Education in

Higher Education

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Concordia University–Portland

2019

Abstract

Critical thinking and reasoning are fundamental skills for a diagnostic medical sonographer. This quantitative quasi-experimental study examined whether teaching diagnostic medical sonography students the scientific method made a significant difference in the student's critical thinking and reasoning skills. Using the Health Science Reasoning Test (HSRT), two groups of students were selected to participate in the study, with a control and experimental group. The HSRT was used to determine if a significant difference in critical thinking and reasoning was discernable from pre-to-post testing between the control and experimental group of students. The data supported teaching the scientific method improved the scores on the post HSRT in the experimental group, which received instruction in the scientific method. A student receiving instruction in the scientific method ($n = 12$) had a higher overall HSRT score ($M = 27$) than the control group ($n = 12$) ($M = 19$), with the difference being statistically significant at $p = 0.05$. Post HSRT testing shows an increase in their national percentile ranking for the posttest, the control group had an increase of 13%, and the experimental group had an increase of 32%. The HSRT can provide educators with a tool to measure the effectiveness of a student's critical thinking and reasoning skills, facilitating their development of bridging didactic and laboratory education to the clinical setting.

Keywords: critical thinking, critical reasoning, sonography, teaching, clinical education

Dedication

Many people have contributed to my successful completion of this project by providing encouragement and support. I dedicate this work to my family: James, Brice, Rachel, Lori, Amy, and Christian. Thank you all for your love, encouragement, and understanding during this process.

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Chapter 1: Introduction

Introduction to the Problem

The diagnostic medical sonographer is a professional in the allied health field, which involves technical competence, interpretive skills, and critical thinking, and reasoning skills. The sonographic images are obtained with the use of specialized equipment, which is the technical component of being a sonographer (Ardms.org, 2019). Every diagnostic medical sonographer is like a detective when it comes to gathering, processing, and analyzing the patient's clinical history and sonographic images. Like a detective, the sonographer is required to exercise critical thinking and reasoning skills in their clinical examination. This is essential as their ability has a direct impact on the interpreting physician's diagnosis (Baun, 2006). Presenting the information and images with optimization and accuracy is essential for the patient's health care and health improvement. The sonographer deals with complex situations that require critical thinking and clinical reasoning skills. Critical thinking and reasoning skills are primarily developed through education and learning (Elder & Paul, 2013).

Background, Context, and History

The use of ultrasound as a diagnostic imaging tool became widespread with commercial applications beginning in 1963. Entry-level sonography positions require an associate degree (U.S. Bureau of Labor, 2019). Diagnostic medical sonographers are a member of the healthcare team providing images of the human body through the use of sound waves. The sonographer evaluates the organs, such as the heart, liver, and kidneys, as well as blood vessels, muscles, tendons, and the fetus. The images are used by a physician to aid in the diagnosis of the patient. Sonography education is at the associates and bachelor degree level. Diagnostic medical sonographers have a national credentialing examination through the American Registry of

Diagnostic Medical Sonographer (ARDMS). The ARDMS credentialing examination and continuing education requirements ensure the sonographer has met requirements to hold the credential (ARDMS.org). Educational programs include clinical experience under the supervision of a credentialed sonographer along with the didactic education for the sonographer's specialty area. Sonographers perform ultrasound examinations and tests that aid physicians in diagnosing the patients' medical problems (U.S. Bureau of Labor, 2019).

Every educational institution must have a well-proven method to develop and accurately gauge the students' ability to transfer knowledge from the classroom to the clinical setting (Penny & Zachariason, 2015). Developing a working measurement and teaching methodology is a challenge and yet very essential for the student, health care professional team, and the patient (Penny & Zachariason, 2015). The focus of the research study is on sonography students in a baccalaureate program of study. The program leads to credentials for Registered Diagnostic Medical Sonographer, through the American Registry of Diagnostic Medical Sonographers (ARDMS). A sonography student must have theoretical and clinical knowledge in order to pass these examinations. Programs in sonography are focused on clinical education hours and the theoretical knowledge as per program accreditation standards (Commission on Accreditation of Allied Health Education Programs [CAAHEP], n.d.). American Philosophical Association Delphi Report, Facione, (1990) and Facione and Facione (2008) defined critical thinking for health care professionals as a process used in making a judgment regarding what to believe and what to do about the symptoms that a patient is presenting for diagnosis and treatment.

Most educators hold the assumption that clinical reasoning and critical thinking skills will be learned through experience in the clinical setting. Modeling the behavior of the clinical instructor does not provide the skill set necessary for the student to develop critical thinking and

reasoning skills in a different vignette (McInerney & Baird, 2016). Students need instruction through learning activities to bridge the didactic or knowledge-based instruction into the clinical setting by analyzing and applying their knowledge as applied to a patient's examination (McInerney & Baird, 2016). Fitzpatrick (2015) asserted that educators realize the need for critical thinking skills but question the best methods for teaching these skills to the student. This is a disadvantage to the student's development of critical thinking and reasoning skills and has an effect on the provision of quality health care to patients in the student's clinical environment and practice (Penny & Zachariason, 2015). Having a method for integrating patient history and sonographic findings from the examination through critical thinking and reasoning is a crucial part of the cognitive functions of the sonographer (Baun, 2004). Critical thinking is the process that the sonographer uses to make a judgment about the patient's history and information obtained from the sonographic images that facilitate the diagnosis and treatment of the patient (Penny & Zachariason, 2015). Therefore, critical thinking and reasoning skills are essential for the sonographer to present the sonographic images with accuracy in facilitating the diagnosis rendered from these images by the interpreting physician. Critical thinking and reasoning skills for the diagnostic medical sonographer are highly essential to the patient's health care and outcome.

Conceptual Framework

The conceptual framework used to ground this study was Paul and Elder's (2019) model of critical thinking. Paul and Elder (2019) developed an eight-step process for students learning to identify, analyze, and evaluate a problem. Paul and Elder's (2019) eight-step method correlates to the five-step scientific method advocated for diagnostic medical sonographers by Baun (2004), and Penny and Zachariason (2015). The Delphi Report defines critical thinking

based on the practitioner's scope of practice, and Facione (1990) equates critical thinking with the scientific process as the method of inquiry. There is an agreement in what critical thinking involves, and as a teaching methodology, the scientific method is supported through the framework of critical thinking combined with the constructivist theory, which encourages reflexivity (Sing & Rajput, 2013).

Statement of the Problem

Every day a sonographer, who is an allied health care professional, must analyze and process the information from clinical histories and sonographic images to provide the interpreting physician with accurate information to make a diagnosis (Penny & Zachariason, 2015). To do this, professional sonographers are required to utilize their critical thinking and better judgment in their examination in order to provide useful information for treatment. Sonography education programs are required to provide instruction that facilitates the development of critical thinking and reasoning skills (Penny & Zachariason, 2015). However, this is not what is experienced in diagnostic medical sonography as the methods of instruction that are currently used do not sufficiently develop these skills among students (Penny & Zachariason, 2015).

Additionally, there is limited literature on critical thinking and reasoning skills in diagnostic medical sonography programs as well as practices (Penny & Zachariason, 2015). There is little research on instructional model effectiveness. Moreover, the scientific method has never been studied to assess its effectiveness towards developing critical thinking and reasoning skills among sonography students as well as medical practitioners (Baun, 2004; Penny & Zachariason, 2015). Critical thinking has been the topic of research studies in nursing and other

allied health programs (Tremel, 2012). However, this has not been the case in diagnostic medical sonography programs. The study seeks to address this research gap.

Critical thinking is a learning outcome included in the National Education Curriculum for diagnostic medical sonography which is a consensus of 18 professional organizations related to sonography (jrcdms.org). The limited research that has been conducted on this topic has established the need for improvement in the critical thinking and reasoning skills of allied health students (Sharp, Reynolds, & Brooks, 2013). One study completed by Sharp, Reynold, and Brooks (2013) concluded that 64.9% of the student participants were in the weak range, 31.6% were in the moderate range, and 3.5% were in the strong range of critical thinking skills. Enhanced critical thinking and reasoning skills are essential for a sonographer as every patient who receives a sonographic examination or ultrasound examination to identify their medical conditions as well as receive proper treatment on their condition for better health care relies upon it (Penny & Zachariason, 2015).

Students in diagnostic medical sonography programs may not be receiving instruction that enhances critical thinking skills and clinical reasoning in the clinical environment. Therefore, the study was designed to provide a methodology of enhancing critical thinking and reasoning skills through the provision of instructions by the scientific method of developing critical thinking in sonography students. Improving critical thinking skills in sonography education through instructional methodology will facilitate bridging the gap between knowledge learned in the diagnostic medical sonography program and its application in the clinical environment (Penny & Zachariason, 2015).

Purpose of the Study

The purpose of this quasi-experimental study was to analyze whether providing

instruction on the scientific method can be used to develop and enhance a student's ability to think critically in a clinical environment. A quasi-experimental research study was used to investigate the effect of employing an instruction model as a scientific method for developing critical thinking and reasoning skills among diagnostic medical sonography students enrolled in bachelor degree programs at universities based on the models of Baun (2004) and Penny and Zachariason (2015). The critical thinking and reasoning skills are essential to accurately interpret sonographic images in the clinical environment by both students and clinical practitioners. The study will further examine the effectiveness of this instructional teaching model in bridging the didactic theory into the clinical practice.

The effectiveness of the sonographic reasoning method (SRM) is evaluated as a scientific method and methodology that educators in different educational institutions may use to improve the student's ability to think critically and reason creatively in the clinical environment. The study investigated the use of instructional methodology using the scientific method to improve the critical thinking and reasoning skills of students and whether there are significant differences in the skills of learners as a result of using the scientific methodology. The emphasis of the study is focusing on establishing whether the scientific method is better at enhancing critical thinking and reasoning skills as compared to nonscientific/traditional methods.

Diagnostic medical sonography programs are taught at different educational institutions as well as various levels, which include certificate and Associate of Science (AS) degrees offered at community colleges, certificates at hospital-based programs, and the Bachelor of Science (BS) degree sponsored by regionally accredited universities. Program accreditation through CAAHEP does not differentiate program standard requirements based on degree level. This means that

bachelor degree programs are not required to meet higher standards than a certificate program or an associate degree program.

Universities offering bachelor degree programs have an obligation to educate diagnostic medical sonography students with not just theory and protocols for sonography examinations and analysis but also focus on developing both their critical thinking and reasoning skills. These skills will enhance clinical practices by sonography students (Baird, 2008). University programs in medical imaging sciences, especially diagnostic medical sonography programs, are obliged to provide instruction that develops and enhances the critical thinking and reasoning skills of medical students (McInerney & Baird, 2016). Evidence in the literature indicates that problem-based learning improves the critical thinking skills of students in nursing and other higher education programs (Savery, 2006; Sharp, Reynolds, & Brooks, 2013; Tsai, 2014).

The main objective of the study is to investigate the validity of the scientific method of instruction model as a methodology for teaching critical thinking and reasoning skills and evaluating its impact on the development of critical thinking skills in students enrolled in the diagnostic medical sonography program.

Specific objectives of the study. The specific objectives of the study include;

1. To assess the level of critical thinking and reasoning skills of the students undertaking the diagnostic medical sonography program.
2. To establish whether there is a significant difference between students who use the scientific method of the instructional model in developing critical thinking and reasoning skills and those who use traditional methods/nonscientific methods.

Research Questions

Two key research questions guided the study in evaluating the effect of instruction using the scientific method in developing critical thinking and reasoning skills among diagnostic medical sonography students include:

1. How significant is teaching diagnostic medical sonography students the scientific method to improve their critical thinking and reasoning skills?
2. How significant is the difference in critical thinking and reasoning skills among diagnostic medical sonography students who receive instruction using the scientific method compared to those who receive instruction using other methods?

Research hypotheses. The study sought to validate the truthfulness of the research hypotheses, which are derived from the research questions of the study. The following research hypothesis presents the null and alternative hypotheses.

H₀: There is no significant difference in the critical thinking and reasoning skills of students who receive instruction using the scientific method and those who receive instruction using the traditional/nonscientific method.

H₁: There is a significant difference in the critical thinking and reasoning skills of students who receive instruction using the scientific method and those who receive instruction using the traditional/nonscientific method.

Rationale Relevance and Significance of the Research Study

The research study contributes to the literature in the field of diagnostic medical sonography by addressing the gap in the literature concerning the use of scientific methods in diagnostic medical sonography programs to improve critical thinking of sonography students (Penny & Zachariason, 2015). The research study offers a significant addition to the information

in the literature concerning the critical thinking and reasoning skills of clinical students and practitioners in diagnostic medical sonography. The study further employs the Health Science Reasoning Test (HSRT), which is an essential critical thinking, and reasoning tool that can differentiate the level of critical thinking and reasoning among students with developed critical thinking and reasoning skills and those with novice critical thinking and reasoning skills.

Sonography education programs provided by educational institutions are required to provide instruction that facilitates the development of critical thinking and reasoning skills (Penny & Zachariason, 2015). Hence, the research study enables universities and other educational institutions offering a diagnostic medical sonography program to acknowledge the essence and importance of the scientific methods instruction model implementation into the diagnostic medical sonography program. Continued use of the scientific method can significantly improve student skills in critical thinking and reasoning as they apply to clinical practice. Further, continued practice using the methodology proposed by the study influences sonography students to be more aware of the entire clinical process.

Sonographers who develop a high level of critical thinking and reasoning skills using the scientific method program are able to think critically and reason while undertaking a sonographic diagnosis of patients. Critical thinking and reasoning skills are crucial for this process, as every patient's encounter is different and produces different results (Penny & Zachariason, 2015). A practicing sonographer is expected to analyze the sonographic images and patient clinical history in the process of obtaining diagnostic images for the interpreting physician to make an accurate diagnosis (Baun, 2006; Penny & Zachariason, 2015).

This study is significant to both students and teachers at universities offering diagnostic medical sonography programs. In the classroom, students are taught the pathophysiology of

diseases along with sonographic characteristics. The study provides information on a scientific method for improving critical thinking in diagnostic medical sonography students and the importance as well as the effectiveness of such methods. Providing such a methodology assists instructors in facilitating student's learning on how to bridge the gap between knowledge learned in the diagnostic medical sonography program and its application in the clinical environment is essential.

Moreover, this study assesses the effectiveness of the scientific method over the nonscientific and traditional methods used to teach critical thinking and reasoning skills for diagnostic medical sonography students. Significant insights gained through the study address the problem of poor decision-making in clinical practices regarding sonographic diagnosis by both practitioners and students in their clinical practices.

The research study employs a quantitative research design. The independent variable of the research study is the scientific method model of instruction, while the dependent variables are critical thinking and reasoning skills. A quasi-experimental research design is used as a strategy of inquiry in establishing whether the scientific method as a treatment/ intervention impacts on the critical thinking and reasoning skills of students as the outcome. Included in the quasi-experimental research design are a pretest and a posttest treatment for the quasi-experimental and control group of the study. Critical thinking and reasoning skills as independent variables will refer to the ability of a student to apply a regulatory judgment of an issue through analyzing, conceptualizing, evaluating, and synthesizing available information.

This study design measures the difference in clinical reasoning skills and critical thinking in students who receive instruction methodology compared to students who have not received the instruction methodology. The HSRT administered to the students is used to measure critical

thinking and reasoning skills. The test is a validated critical thinking skills test with questions that are stated in a health science context (Cox & McLaughlin, 2014); it is designed to measure the critical thinking of both professional practitioners and students in health sciences educational programs (Cox & McLaughlin, 2014). The HSRT is commercially available and is used in different health disciplines. The HSRT has been used in research to evaluate critical thinking skills and clinical performance through multiple choice questions targeting critical thinking of health care professionals and students. Additionally, a survey design will be adapted to assess the ability of the students to bridge didactic and critical thinking skills in a clinical setting. Focused questions in the survey design to evaluate the students in a clinical setting will be administered to both groups via the internet through Trajecsys™.

Definition of Terms

Accredited education program: It refers to an entry-level program in diagnostic medical sonography, which is recognized by CAAHEP. These programs must meet published standards by the JRC-DMS and CAAHEP, which provide students with an appropriate didactic, and clinical educational experience to ensure their eligibility to take the national credential examinations with essential patient care skills and knowledge base. The examinations are offered by the ARDMS and ARRT (CAAHEP, 2009).

American Registry of Diagnostic Medical Sonographers (ARDMS): An international credentialing nonprofit organization for sonography professionals promoting quality patient care through the certification and continuing competency of the diagnostic medical sonographer (ARDMS, 2016).

American Registry of Radiologic Technologists (ARRT): International organization that credentials are imaging technologists, which includes diagnostic medical sonography (ARRT, 2016).

Clinical education: The application or practical component of the educational program during which the student practices under the supervision of a credentialed clinical supervisor and the program on real patients in the community healthcare facilities, which are hospitals, and outpatient centers (JRC-DMS, 2016).

Commission on Accreditation of Allied Health Education Programs (CAAHEP): CAAHEP is a programmatic accreditor in the health sciences field recognized by the Council for Higher Education Accreditation (CHEA). CAAHEP, in collaboration with its Committees on Accreditation reviews and accredits sonography programs in educational institutions (CAAHEP, 2009).

Critical thinking: Involves asking appropriate questions, gathering and sorting relevant information, evaluating new information with existing knowledge, reasoning logically, and arriving at reliable conclusions (Gokhale, 2012).

Diagnostic medical sonography: It refers to an imaging modality that uses non-ionizing ultrasound (sound waves) to produce 2D and 3D images of the body. Sonographic images are interpreted by a licensed physician (Occupational Outlook Handbook, 2019).

Joint Review Committee on Education in Diagnostic Medical Sonography (JRC-DMS): A nonprofit organization that has been in existence since 1983 to establish, maintain, and promotes quality standards for education programs, specifically Diagnostic Medical Sonography (JRC-DMS, 2016).

Laboratory Course: The practical application of established practice standards or protocols of sonographic examination. The classroom theory is applied in this setting while allowing the student to develop the psychomotor skills necessary to obtain diagnostic sonographic images (JRC-DMS, 2016).

National Education Curriculum for Sonography (NEC): It refers to a working product of a national consensus involving multiple sonography-related professional organizations (JRC-DMS, 2016).

Practice Standards: These are practice standards suggested by the American Institute of Ultrasound in Medicine (AIUM) and American College of Radiography as the two primary physician organizations establishing the practice standards (AIUM.org).

Professional Sonographer: It refers to an allied health professional highly skilled in performing the diagnostic medical examination (Occupational Outlook Handbook, 2019).

Assumptions, Delimitations, and Limitations

Assumptions. The research study assumed that the sonography students receiving intervention through the scientific method to enhance and develop their critical thinking and reasoning skills would show a greater significant difference and improvement in their critical thinking and reasoning skills in posttest and focuses assessment at the end of the semester. A further assumption that results obtained in both the pretest and posttests on the assessment of critical thinking and reasoning skills in diagnostic medical sonography students are not affected by external and other factors such as age and student's background.

Another assumption of the study is the homogeneity of participants in the study; the assumption considers second-year sonography student participants are similar in all aspects to be assessed on their level of critical thinking and reasoning skills in the research study.

Delimitations. Delimitations are the shortcomings of the study beyond the researcher's control (Stenbacka, 2001). Several delimitations characterize the study. Participants will only be recruited from second-year students enrolled in the diagnostic medical sonography program. The study was only conducted for one semester. Of the total participants, 12 will be in the control group, and 12 will be in the quasi-experimental group. The quasi-experimental design was selected for the research study because it was not possible to assign the participants to quasi-experimental and control groups randomly (Creswell, 2016).

Limitations. Various limitations affect the research study and the applicability of the research to other educational settings. There is limited literature covering critical thinking and reasoning in diagnostic medical sonography and imaging sciences. The research study employs a quantitative design to assess critical thinking. However, critical reasoning skills are more subjective and are better analyzed qualitatively (Facione & Facione, 2013). The research study is conducted on a small number of participants limiting the study to arrive at a more conclusive result; hence, the study may not be generalized and applied to all diagnostic medical sonography programs.

The study only assesses the critical thinking of students from a single educational institution rather than conducting it on several institutions to improve on the applicability of the findings from the research. The results of the study are unique to a single institution. The assessment is the use of the HSRT as the only tool for assessing the critical thinking and reasoning skills of sonography students and does not consider any other critical thinking tool such as the California Critical Thinking Skills Test (CCTST) in the assessment process. The study is limited to the use of TrajecsysTM to enable the administration of the focused questions to the sonography students as not all the clinical preceptors may have access to the Internet.

The study assesses second-year students who are in different sections of the same course; both groups receive the same instructions while the quasi-experimental group receives additional instruction in using the scientific method. In the students' junior year, both groups received the same instruction and attended the same course sections. A random selection of the participants to the quasi-experimental group and control group was not possible given that the instruction model using the scientific method is delivered only to the second-year students based on their assigned lab section. Hence, critical thinking and reasoning skills may not be similar at the baseline (Beaumont, 2009). Moreover, the research study will only be carried out on a single semester rather than a full academic year or the whole period of the bachelor degree program.

Summary

A sonographer is required to exercise critical thinking and reasoning skills in clinical examination. Presenting the information and images with optimization and accuracy is essential for patient health care and health improvement. Educators hold the assumption that clinical reasoning and critical thinking skills will be learned through experience in the clinical setting, which is a disadvantage to the student (Panettieri, 2015).

Educational programs in diagnostic medical sonography are challenged to provide instruction that facilitates the development of critical thinking and reasoning skills for sonography students (Penny & Zachariason, 2015). The methods of instruction that are currently used do not sufficiently develop or measure these skills among the students (Penny & Zachariason, 2015). The focus of the study is on developing a methodology to enhance student critical thinking and reasoning skills. The purpose of the study is to evaluate the effectiveness of the instruction model as a scientific method in developing critical thinking and reasoning skills among students enrolled in a diagnostic medical sonography program. Critical thinking and

reasoning skills are essential for the sonographer to present the sonographic images with accuracy in facilitating the diagnosis rendered from these images by the interpreting physician. In Chapter 2, the literature review will look at research done by other scholars related to the topic and further identify studies supporting the research topic. In Chapter 3, the methodology section will further present the design and method of data collection and analysis used in the research study.

Chapter 2: Literature Review

Introduction to the Literature Review

Poorly reasoned clinical decisions have significant consequences on the lives of patients and their families. Heriot, McKelvie, and Pitman (2009) comprehensively studied reported errors in the radiology department finding 250 diagnostic patient report errors. Heriot et al. established that 90% of incorrectly reported patient diagnosis were due to human error. Competent critical thinking and reasoning are essential outcomes in educational programs that help to reduce such errors. As such, implementing practical pedagogical approaches for allied health professions that develop these skills among students will reduce the human error contribution to poor patient outcomes (Facione & Facione, 2008).

The most significant skill students must learn in the diagnostic medical sonography program is to think critically (Penny & Zachariason, 2015). Many students are unable to grasp the importance of critical thinking or reasoning, but it is essential for the clinical sonographer to have the ability to evaluate and process information, problem-solve and reach accurate conclusions (Penny & Zachariason, 2015). Professionals in allied health programs, including dental hygiene, radiology technology, respiratory therapy, physical therapy, and diagnostic medical sonography, realize that critical thinking skills are necessary for the profession (Fitzpatrick, 2005). Questions arise as to how to approach, measure, encourage, and teach these skills (Fitzpatrick, 2005).

The literature review examines the history of teaching pedagogies in critical thinking and suggested teaching applications to diagnostic medical sonography in allied health programs at the collegiate level (McInerney & Baird, 201). Lectures are the norm for teaching imaging, along with having the students memorize and retain the information presented (Kowalczyk,

Hackworth, & Case-Smith, 2012). A review of the literature indicated there are multiple studies suggesting methods of teaching critical thinking and reasoning but without measurable outcomes of student learning, including those by Baun (2004), Penny and Zachariason (2015), and Wilson, Remlinger, and Wilson (2010). The study focuses on developing critical thinking skills in the allied health professions, specifically diagnostic medical sonography by reviewing (a) the conceptual and theoretical framework established, (b) conceptual mapping and scientific instruction, and (c) recent research on critical thinking and reasoning instruction within the field of diagnostic medical sonography.

Conceptual Framework

Critical thinking and reasoning are vital skills for the student becoming a professional diagnostic medical sonographer to develop, as patients' treatment depends on their accuracy in analyzing data. Lives depend on competent clinical reasoning, and educators should strive to instill critical thinking skills (Facione & Facione, 2008; McGarrity, 2013). The concern for students struggling in the clinical setting with critical thinking and reasoning skills form part of the basis for this dissertation study. These concerns are supported by Foster and Lemus's (2014) research with astrobiology students who were asked about their confidence in applying these critical thinking skills into professional practice, only 30% to 40% of students indicated they would be able to apply critical thinking and reasoning skills.

Baun (2004) first proposed using the scientific method for the sonographic examination. The model of the scientific method in sonography is to provide a framework for what to observe and how to interpret and use the information (Baun, 2004). Observation is the first element, based on information received prior to the study, subjective in nature, and used by the sonographer to form the hypothesis, the second element of the scientific method. The hypothesis

is what the sonographer needs to observe when collecting the data through the images, which is the third element, the organization of the observations. The fourth element is the analysis and interpretation of the data collected. The conclusion or interpretation of the data is the fifth element in the scientific process (Baun, 2004). The sonographic reasoning model expanded on Baun's (2004) application of the scientific method to improve critical thinking skills and reasoning (Penny & Zachariason, 2015).

Multiple researchers have analyzed the strategies for teaching critical thinking skills (Baun, 2004; Penny & Zachariason, 2015). Case study analysis is one strategy that promotes the learning of critical thinking skills. Case studies can be an individual or group project presented in the classroom or online (McInerney & Baird, 2016; Penny & Zachariason, 2015). Anecdotal methods allow the student to think and solve the scenario. Role-playing is another method of learning patient communication skills, which helps in obtaining an accurate patient history. Students involved in a clinical case first learn protocols, which meet specific criteria, for each examination. Once having this foundation, the student can use reasoning skills and make deductions based on their clinical experiences and the patients' history (McInerney & Baird, 2016; Penny & Zachariason, 2015).

The constructivist theory forms the basis for this study, along with the concept of personalized learning. Students become active participants in their learning while the professor facilitates the process, which instills critical thinking skills, so students are not memorizing and regurgitating facts without the ability to analyze and interpret the information (McGarrity, 2013; Zmuda, Curtis, & Ullman, 2015). The constructivist approach encourages reflexivity (Singh & Rajput, 2013). Reflexivity is the process where the student becomes an active participant

developing an awareness of their thinking processing (McGarrity, 2013; Singh & Rajput, 2013; Zmuda et al., 2015).

Constructivism consists of three categories: cognitive, social, and radical (Singh & Rajput, 2013). Dewey advocated inquiry of information beyond acquisition. The development of acquired information into knowledge is not possible without critical thinking and reasoning (McInerney & Baird, 2016; Singh & Rajput, 2013). Vygotsky modified Piaget's constructivist theory to include the social experiences of the learner (Kivunja, 2014; Vygotsky 1929). Vygotsky theorized that learning is a social experience and involves dynamic learning with others (Kivunja, 2014; Singh & Rajput, 2013). Radical constructivism is adaptively recognizing knowledge acquisition in the individual learner, along with social interactions as a source of knowledge (Singh & Rajput, 2013). As such, the development of knowledge results from both social interactions and experiences those learners undergo. DMS students use this approach to obtain patient history and present the information from the examination to the interpreting physician.

Students need to connect their knowledge to experiential experiences, which occur in the laboratory courses and clinical experience. Using the scientific method as a model for critical thinking and reasoning as the student must analyze the clinical history and sonographic findings to accurately present the information to the interpreting physician (Baun, 2004; Perry & Zachariason, 2015). Kolb (2014) and Schön (1983, 2016) refined Dewey's model and created models for reflective practice. The models differ, but the requirements include experience, think, and learn (McInerney & Baird, 2016).

In this study, the conceptual framework for critical thinking and reasoning is blended to validate and assess the outcomes of teaching critical thinking and reasoning skills. This

framework calls for evaluating methodology based on the scientific method and validating the outcomes of students critical 'thinking and reasoning skills. Students at the degree level must do more than following protocols for obtaining relevant images. The students must be able to vary the protocols to encompass anomalies and pathologies, which involve critical thinking skills to solve the dilemmas and provide correct information (McInerney & Baird, 2016). There is a need for developing a pedagogical approach that will integrate critical thinking and reasoning skills. The current study aims to evaluate whether the scientific model can impart both critical thinking and reasoning skills.

Review of Research Literature and Methodological Literature

While reviewing the literature, I determined patterns within the research that could help identify how to teach and assess critical thinking and reasoning skills to diagnostic medical sonography students. The literature review covers the definition, history of critical thinking, critical thinking in the allied health professions, and diagnostic medical sonography. I analyzed and cross-referenced the allied health professions and diagnostic medical sonography to develop a measurable teaching methodology of critical thinking and reasoning skills.

History of critical thinking. Philosophers, whose theories framed critical thinking, include Socrates and Plato. Socrates and Plato encouraged students to question information and not accept information as presented (Paul, Elder, & Bartell, 2009). Socrates' method was to question and reason concepts while looking deeper to see if there are other implications (Paul et al., 2009; Tanenbaum, Tilson, Cross, Rodgers, & Dowd, 1997). Socrates' style of learning is student-centered and involves the importance of student analyzing, questioning, and factoring the outcomes. Socrates' style encourages students to ask questions and think for themselves while preparing for the counterargument (Tallent & Barnes, 2015).

Socrates' theory was expanded by Piaget to include the cognitive development aspect (Huitt & Hummel, 2003). According to this aspect, an individual learns information and then uses individual experiences to reason and draw conclusions (Huitt & Hummel, 2003). Piaget identified four stages of cognitive development that relate to behavior and growth from infancy to adulthood (Huitt & Hummel, 2003). The four stages of cognitive development are motor / sensory infants, pre-operational / toddlers and early childhood, detailed operational / elementary and early adolescent, and formal operations stage / late adolescents to adult (Huitt & Hummel, 2003). The teaching pedagogy for the millennial generation takes critical thinking out of the equation, instead of telling the students how and what to learn and what to know for the test is expected (Tallent & Barnes, 2015).

Defining the meaning of critical thinking varies as critical thinking has become a prime objective for measurement of accountability for colleges and universities, indicating that critical thinking is necessary for students to move from passive to learners utilizing thinking and reasoning (Stassen, Herrington, & Henderson, 2011). Critical thinking education is now an integral part of undergraduate education, spreading across all disciplines (Lampert, 2007). Obtaining critical thinking skills across the curriculum is a desired skill and goal of higher education (Stassen, Herrington, & Henderson, 2011). Reflective reasoning about actions and beliefs is one definition of critical thinking (Lambert, 2007). Critical thinking allows the thinker to examine ideas, assumptions, clarify and determine a conclusion, which should be part of the academic learning process in higher education (Sharp, Reynolds, & Brooks, 2013).

Critical thinking in allied health professions. Radiology Technology is another imaging science, which faces the same issues with critical thinking as sonography. Both professions programmatic accreditation requires teaching the specific curriculum, which includes

protocols for performing the imaging examinations (Gosnell, 2010). The nursing profession first embraced problem solving equated with critical thinking. However, Fitzpatrick (2005) indicated that improvement is still needed in critical thinking in the nursing profession as the current instruction focuses on practical application rather than critical reasoning. Practice application is direct patient care the students are providing without a connection to didactic learning and critical thinking skills, which include decision-making and analysis, with supervision from faculty (McNelis et al., 2014). Practice application limits the graduates' ability to reason, analyze, adapt techniques, and problem solving to produce an optimal finished product (Zygmunt & Schafer, 2006). Australia's Department of Medical Imaging and Radiological Sciences considers the ability of the radiographer to apply critical thinking skills to clinical practice, a standard code of conduct, and not an option (McInerney & Baird, 2015).

Congress (Goals 2000: Educate America Act, 1994) listed critical thinking as a specific educational outcome. The Joint Review Committee on Education in Diagnostic Medical Sonography (JRC-DMS) responsibility is programmatic accreditation, which began incorporating cognitive skills and critical thinking into the requirements (Joint Review Committee on Education in Diagnostic Medical Sonography (JRC-DMS), 2011). The Commission on Accreditation of Allied Health Education Programs (CAAHEP) Section II.C. affective in preparing the student to become an entry-level sonographer (CAAHEP, 2011).

The challenge for educators is to shift teaching paradigms from the knowledge and task-based learning to adopt 21st-century learning and innovation skills, which complement the necessary digital literacy skills for students to be successful at all levels (Kivunja, 2014; McInerney & Baird, 2016). Degree level students must have critical thinking and reasoning skills to do more than implementing protocols (Baird, 2008; Ng, White, McKay, 2008). It is essential

that healthcare workers have critical thinking and reasoning skills as patients' lives are in the balance (Facione & Facione, 2008).

Critical thinking in diagnostic medical sonography. Critical thinking is a crucial component of clinical sonography in how the sonographer evaluates both the patient's clinical history and the sonographic findings during the examination (Penny & Zachariason, 2015). Critical thinking is a fundamental skill necessary for sonography. Critical thinking involves the cognitive and affective domains of reasoning, which is a process, such as the scientific method, to process and analyze the information (Baun, 2004; Simpson & Courtney, 2002). Baun (2004) stated that applying the scientific method in medical sonography involves making observations, hypothesis, data collection, data analysis, and conclusion.

Penny and Zachariason (2015) discussed models for improving critical thinking and reasoning skills for the student sonographer. The SRM is a framework for a five-step process based on the scientific method, which combines critical thinking and reasoning skills to facilitate the students' development of these skills (Penny & Zachariason, 2015). Penny and Zachariason (2015) devised the acronym "IMAGE" for the process to help students remember the steps: investigate the history, make hypotheses, analyze with sonography, gather all sonographic findings, and evaluate for connections. The scientific method of evaluation is simplified by using the SRM (Penny & Zachariason, 2015).

Although the stress in higher education is on the development of critical thinking skills in students, in allied health education, the development of these skills is in the early stages (Sharp, Reynolds, & Brooks, 2013). Allied health professionals, including diagnostic medical sonographers, have many responsibilities within their scope of practice, including being part of

the healthcare team delivering quality patient care. Critical thinking and reasoning skills are crucial to the process and outcomes (Sharp, Reynolds, & Brooks, 2013).

Baun (2004) first introduced the concept of applying the scientific method as a model to organize observation, data, and how to interpret the history and sonographic information. Baun (2004) advocated developing this into an approach for every sonographic examination, and to format this method into teaching and evaluating the critical thinking of sonography students. Even though this process is discussed in educational circles, there are no studies that have explored the use of the scientific method approach in sonography. Penny and Zachariason (2015) expanded on Baun's (2004) original concept, developing a systematic mnemonic to impart steps leading to the critical thinking process. Neither process has been thoroughly researched as a valid method to ensure students are developing the critical thinking and reasoning skills (Baun, 2004; Penny & Zachariason, 2015).

Critical thinking defined. Critical thinking includes multiple skill sets, which included evaluation, deduction, induction, analysis, and inference, which are all part of the scientific method (McGarrity, 2013). Another component to reaching a diagnosis involves critical reasoning. Critical reasoning is metacognitive, where the sonographer processes the patient's signs and symptoms and information gathered during the acquisition of sonographic images and information (McGarrity, 2013; Simmons, 2010). Critical reasoning is a complex process that uses the diagnostic medical sonographers' knowledge to gather and analyze patient information, correlate and evaluate the significance while obtaining diagnostic sonographic images for interpretation by the physician (Simmons, 2010).

Models of teaching critical thinking skills. Bloom (1956) describes different models that are used to teach critical thinking skills (Chaffee, 2019; Nosich, 2012; Overbaugh &

Schultz, 2008). Bloom's taxonomy of learning continuum indicates that learning begins with the acquisition of knowledge and moves through the pyramid to higher levels of learning. The base level of Bloom's taxonomy is the acquisition of knowledge, followed by comprehension, application, analysis, synthesis, and evaluation (Kiong, Yunos, Mohamad, Othman, & Heong, 2010). Bloom (1956) defined his original taxonomy, with six areas of the learning process, which covered the cognitive, affective, and psychomotor domains.

The steps through Bloom's (1956) pyramid begin with the acquisition of knowledge and the ability to recall knowledge. Comprehension follows knowledge whereby the student gains an understanding of the material. The application is where the student applies the understanding of the knowledge of new concepts, thus solidifying the comprehension. Following the application is an analysis that has the student showing an understanding of the content and how to apply the material in a different context.

Synthesis creates new connections from the analysis. The final step includes all previous levels, whereas the evaluation has determined the purpose and value of the subject material. Since evaluation utilizes all the steps above, it is considered the highest in the hierarchy of Bloom's (1956) taxonomy. Bloom's (1956) became a standard to gauge the learning and progress of students through all grade levels (Overbaugh & Schultz, 2008).

A revision of Bloom's taxonomy by two of his students, Anderson and Krathwohl (2001), updated the taxonomy to include other levels of knowledge that include actual, procedural, conceptual, and metacognitive. The improved revision of the model cultivates thinking through intertwining major types of knowledge, including factual, conceptual, procedural, and metacognitive (Kiong, Yunos, Mohamad, Othman & Heong, 2010). Nosich (2012) and Chaffee (2019) provide guidelines that correlate to Bloom's Taxonomy in line with

the respective critical thinking models. Clarifying is the first step in critical thinking. Nosich (2012) uses the model SEE-I for the four-step clarification process requires that S is for state it, E is for elaborate, E is for exemplify, and I is for illustrating. Nosich's (2012) model also corresponds to Paul and Elder's (2019) model of critical thinking. Paul and Elder's (2019) model consists of eight standards, which include clarity, accuracy, precisions, relevance, depth, breadth, logic, and fairness. Through the eight-step process, the student is able to identify, analyze, and evaluate a problem. The model of critical thinking developed by Paul and Elder (2019) holds that the student should strive to achieve the eight standards of critical thinking and apply them to any problem that needs solving. Paul and Elder (2019) are credited with developing the Foundation for Critical Thinking.

Critical thinking scale. The Delphi Report developed a consensus for defining critical thinking based on the practitioner's scope of practice that results in the analysis, evaluation, and inference of context based on evidence. Facione (1990) holds one view defining critical thinking as a purposive and self-regulatory judgment that involves interpreting, analyzing, evaluating, making inferences, and explaining evidential and contextual consideration. The second view of the Delphi report equates critical thinking with an inquiry that is part of the scientific method or process, which is supported by Baun (2004), Penny, and Zachariason (2015) and (Facione, 1990). Facione established The California Academic Press in 1986, which is now known as Insight Assessment.

Insight Assessments developed the CCTST and the HSRT as measures of critical thinking skills. CCTST assesses critical thinking skills in an educational or workplace environment. Testing allows the student to demonstrate their skills in critical thinking through solving problems. Insight Assessment researches critical thinking through developing specific

tests that measure cognitive skills along with providing understanding and methods of teaching through analyzing the data collected. Critical thinking, which is a component of cognitive thinking, applies the scientific methodology to include observation, hypothesis, data collection, data analysis, and conclusion (Baun, 2004).

A quantitative study conducted by Khallli (2009) evaluated the construct validity, content validity, and reliability of CCTST using nursing students and philosophy students. The study established that the test was effective in differentiating between nursing students who had received instruction in critical thinking and philosophy students who did not have any instruction on critical thinking. Khallli's (2009) study was confirmed by another study by Tsai (2014) to evaluate the use of CCTST as a test for measuring the critical thinking skills of the students being admitted to the dental education program. Both studies found the CCTST to be a reliable measure of critical thinking skills for allied health students.

The Health Science Reasoning Test (HSRT) is specific to critical thinking in the healthcare setting developed by Insight Assessments. HSRT is a 33 multiple-choice question examination that can be administered online or as a traditional paper test. The HSRT evaluates the overall critical thinking score and includes analysis, evaluation, inference, deduction, and induction. The exam is not unique to health science knowledge, but the item vignettes are placed in the healthcare setting, versus everyday life settings as in the CCTST. Facione and Facione (2013) posited that an overall score of 15 to 20 equates to moderate critical thinking ability, 21 to 25 equates to strong critical thinking ability and scores greater than 25 equates to superior critical thinking skills. Additional scoring for the subsets are evaluated, with a score above five indicating strong analysis, inference, and evaluation skills while a score above eight equates strong deduction and induction skills (Facione & Facione, 2013).

Quantitative studies have been conducted to evaluate the construct validity of the Health Science Reasoning Test (HSRT). Huhn, Black, Jensen, and Deutsch (2011) conducted a study with physical therapy students to determine if the HSRT could differentiate individuals with novice critical thinking skills from those with expert critical thinking skills. The total overall critical thinking scores were compared with an independent *t*-test, and the subsets were evaluated using ANOVA (Huhn et al., 2011). The findings of the study established that HSRT could discriminate between students with expert and novice critical thinking skills. Another study conducted by Sharp, Reynolds, and Brooks (2013) used the HSRT to measure the critical thinking skills of students. The findings of the evaluation indicated that 64.9% of the students had weak critical thinking skills, whereas only 3.5% of the students had strong critical thinking skills. A one-way ANOVA was used to determine if the varying academic levels had an impact on critical thinking skills. The findings showed that there were statistically significant differences at $p < 0.05$ for different academic levels. The bachelor-level scores were lower than the master-level students (Sharp et al., 2013) were. Both studies evaluated and confirmed through the use of the HSRT and ANOVA testing that critical thinking skills differences could be distinguished between novice and experienced or undergraduate and graduate students (Huhn et al., 2011; Sharp et al., 2013).

Another quantitative study conducted by Sharp, Reynolds, and Brooks (2013) used HSRT to examine the critical thinking of 57 health informatics and allied health students who were graduating from a university located in the southeastern United States. The researchers used the Cronbach alpha to determine the reliability of the test and the five scales that make up the total score. The HSRT includes analysis and interpretation, inference, evaluation, inductive reasoning, and deductive reasoning in the overall internal reliability determined by the Cronbach

scale. Sharp, Reynolds, and Brooks (2013) used the HSRT in a study which resulted in an internal consistency value where $\alpha = 0.85$ falling within the accepted alpha value of $\alpha = 0.70$ and $\alpha = 1.0$ that indicates that the test has internal consistency. Cronbach alpha was within the accepted range for reliability for the analysis of the overall score and the five scales of the HSRT, which are included in the overall score. Cronbach alpha is not designed to determine the reliability of a single multiple-choice question, but the overall scores of the HSRT.

The HSRT, through research by various allied health professionals, has shown the test to be a validated measurement of critical thinking and reasoning skills. Quantitative studies by Huhn et al. (2011) and Sharp et al., 2013, demonstrated the internal consistency of the HSRT. Huhn et al., using an ANOVA showed the HSRT was able to distinguish a difference in the critical thinking ability of students based on their level of education. Insight Assessment critical thinking tests were validated by Khallli (2009) and Tsai (2014) as being reliable as an admission requirement to allied health programs.

Review of Methodological Issues

The methodological issues of teaching critical thinking and reasoning are reviewed to demonstrate the gap present in having a validated testing method of assessing critical thinking and reasoning skills. As the review shows, the assessments are primarily subjective, with no validated assessments for diagnostic medical sonography. The selected methodology for validating the HSRT in this study was the scientific method introduced in sonographer literature by Baun.

Critical thinking instructional practices. Critical thinking teaching involves using a platform that differs from passive lecturing. The social constructivist style of the pedagogy allows for student-centered learning, which involves building a community of inquiry in the

classroom (Tallent & Barnes, 2015). The community of inquiry framework established by Garrison, Anderson, and Archer (2010) described a convergence of interrelated ideas that, when combined, work to facilitate an active, collaborative learning environment. Teaching, cognitive, and social are the three presences in the community of inquiry. The three presences form part of the model to a positive collaborative educational environment (Akyol & Garrison, 2011; Garrison et al., 2010; Garrison, Cleveland-Innes, & Fung, 2010; Garrison & Arbaugh, 2007).

Social presence places the students and instructors in a community brought together by the subject matter in which learning occurs through developing interpersonal communications and relationships in a secure classroom environment (Garrison, 2007). Participants included in the social community are the instructor and the students. Social presence is a level of trust that develops peer to peer and peer to instructor relationships. Students report that the standard of social presence correlates with course satisfaction (Joo, Lim, & Kim, 2011; Shea, 2006; Stodel, Thompson, & Macdonald, 2006).

Cognitive presence is just as crucial to the learning process as a social presence. Cognitive presence is active learning where the learner connects through the reflection of individual experience (Garrison et al., 2001). The definition of cognitive presence is of, relating to, being, or involving conscious intellectual activity (as thinking, reasoning, or remembering; Chaffee, 2019).

The first step in cognitive presence is the observations, hypothesis, and data compilation of the scientific process. Cognitive presence includes practical inquiry, which is rational as a component of the instructional models, which is included in the scientific method (Garrison et al., 2010, 2001; Garrison et al., 2010). The practical inquiry is the second step that complements and completes the cognitive process. Students integrate their new understanding and apply it to

the outcome. When the students' practical inquiry follows the method and evaluates the results, the student will be encouraged to continue the process. Critical thinking is not easy to learn, and it takes practice to master the skills. Gelder (2005) equates learning critical thinking and reasoning to an adult achieving fluency in a foreign language. The faculty has the responsibility to create a collaborative learning environment that embraces social and cognitive presence.

Teaching presence encompasses a multitude of factors including design, faculty direction, and facilitation to create a meaningful learning environment that meets the cognitive and social needs of the learner (Anderson, Rourke, Garrison, & Archer, 2001). Teaching presence will have measurable outcomes (Anderson et al., 2001). Instructor course design is the teaching presence that directs the educational activities to create cognitive and social educational learning in the classroom (Anderson et al., 2001). Establishing a teaching presence in the classroom is through facilitation by the instructor.

There are many ways in which instructors can incorporate a strong teaching presence in their classroom, such as specific content design, which includes learning outcomes, prompting discussions, summarizing discussions, encouraging participation, and providing timely feedback. The goal is to create an environment where the student is eager to be online and participate in the course. Ultimately, the instructor's presence is what distinguishes a successful class from self-directed education (Garrison & Arbaugh, 2007).

The community of inquiry provides a model for classroom and online instructors to implement learning in an online environment through the inclusion of social presence, cognitive presence and teaching presence (Garrison et al., 2010; Garrison et al., 2010). Using the scientific method in critical thinking correlates with the cognitive presence, which alone would not support

a rigorous course (Baun, 2004). The addition of social and teaching presences are necessary for the entire course framework to be a successful learning environment.

The instructor who successfully integrates all three components of the community of inquiry will create a presence in the classroom that benefits student learning (Garrison et al., 2010; Garrison & Arbaugh, 2007; Garrison et al., 2010). Communities of practice, as defined by Wenger (2006), bridge the gap between academic and the clinical setting, defines people engaging in a shared learning and community, such as a hospital brought together for the same purpose.

Trilling and Fadel (2009) outlined the skills that are needed for critical thinking and problem solving among students in the 21st century. These include innovation skills and active learning skills. Technology provides a support network to critical thinking by allowing access to experts in the field, the ability to manage, store, and analyze information necessary to make decisions (Trilling & Fadel, 2009). Digital literacy and reasoning skills are essential for online communication and collaboration (Trilling & Fadel, 2009).

Millennial students are accustomed to working through a problem; having the right answer provided beforehand, so basing instruction exclusively on the use of reasoning skills is difficult for them (Trilling & Fadel, 2009). Grigg (2017) supported the blending of the learning approach, which involves stimulating the student's mind, encouraging the student to think outside the norm, increasing their ability to think and reason critically.

Scientific method for instruction. There is limited research literature that pertains to the effect of the use of the scientific method model in the development of critical thinking and reasoning skills (Penny & Zachariason, 2015; Foster & Lemus, 2015). Extant literature indicates that the scientific method to be effective in the development of critical thinking skills among

students (Foster & Lemus, 2015). Emphasis is often placed on knowledge transmission rather than enhancing the ability of students to integrate, analyze, and synthesize facts. Foster and Lemus (2015) conducted a study to explore the application of the scientific method in astrobiology students and found that the scientific method significantly increases the post-course knowledge and critical thinking skills among students. The study indicated that there is a need for incorporation of the scientific method in other fields, especially in health education, where the ability to think and reason critically is of utmost importance. No studies were found in an extensive literature search that has explored the incorporation of the scientific method in sonographic examinations or its impact on developing critical thinking and reasoning skills since it was introduced by Baun (2004).

Several studies (Latif, Mohamed, Dahlan, & Nor, 2016) have examined the effect of using various learning activities in medical education to develop critical thinking and reasoning skills among students. The inclusion of different learning activities is in response to increasing importance that is attached to teaching and learning of these skills by professionals in the medical field in order to bridge theory and clinical practice among students (Latif et al., 2016).

The teaching, assessing of critical, and thinking skills have emerged as a priority in medical education (Huang, Newman, & Schwartzstein, 2014). Lasker (2016) highlighted the need to employ the best pedagogic approaches to ensure students graduate with the necessary skills that will contribute to their employability and strengthen their capacity to work in clinical situations. Some of the proposed strategies that promote critical thinking and reasoning skills among students include concept mapping and simulation.

Concept mapping. Though educators may be successful in the teaching of the basics, it does not always translate to the ability of students to understand and evaluate the knowledge

learned in academic theory and applying it in clinical situations (Latif, Mohamed, Dahlan, & Nor, 2016). As such, there is a need for educators to adapt learning and teaching methods that promote critical thinking. Developing critical thinking among students is a challenge facing many educators. The promotion of critical thinking skills requires the construction and reconstruction of concepts by learners through active seeking and integration of new and old knowledge (Latif et al., 2016). Concept mapping is one of the instructional strategies that are studied to enhance student learning of critical thinking skills.

Concept mapping was developed by Novak (1977) as an instructional model that enables learners to integrate new knowledge into existing knowledge frameworks as well as allow preceptors to monitor the development of new frameworks of knowledge by their students after instruction (Bixler, Brown, Way, Ledford, & Mahan, 2015). Bixler et al. (2015) used concept mapping as an intervention in study a pretest-posttest single group experimental research design study. The researchers employed the California Critical Thinking Skills Test (CCTST) to assess the critical thinking skills of 27 students before and after the delivery of concept mapping as an intervention for four weeks.

Bixler et al. (2015) hypothesized that concept mapping activities would enhance knowledge acquisition and develop student's critical thinking skills. The findings indicated no significant differences between the pretest and posttest overall CCTST scores. Attributing to no significant differences is the fact that the students had achieved high scores during the pretest, which thereby limited the ability to detect gains in critical skills thinking after the delivery of concept mapping. Senior students who had nearly completed comprised the sample in the study. Possibly the student training had contributed to strong critical thinking skills skewing the

findings. The study provides a guide for further research aimed at studying learning activities that improve critical thinking skills in health professionals.

Further study by Latif et al. (2016) investigated concept mapping as an education and learning tool in the development of critical thinking skills among nursing students that encourage them to connect new information to their prior knowledge. The researchers reviewed past studies regarding the use of concept mapping in nursing education. The findings indicated that concept mapping could improve critical thinking skills among nursing students and allow students to transfer and apply didactic knowledge to clinical practice. In addition, it makes learning more meaningful and effective. There is a need for more research to validate that educators should embrace concept mapping as a teaching tool for the promotion of critical thinking skills.

A quantitative study by Atay and Karabacak (2012) explored the impact of concept mapping on critical thinking dispositions of students. The researchers employed a two-group pretest posttest experimental research design. Eighty participants, who included first-year and second-year students, were recruited and randomly assigned to an experimental and control group. The groups' critical thinking dispositions were pretested and posttested using the California Critical Thinking Disposition Inventory. The researchers used concept mapping as an intervention in increasing the critical thinking capability of students.

Considering the findings, Atay and Karabacak (2012) asserted that concept mapping is an effective tool in increasing the critical thinking skills of students. Results of the study by Atay and Karabacak (2012) indicated that there were no statistically significant differences between the pretest scores between the experimental and control groups. Statistically, significant differences were evident between the two groups in the posttest scores, indicating that the two groups were similar regarding their critical thinking dispositions before the intervention, but the

experimental group had a significant improvement regarding the critical thinking compared to the control group. Concept mapping has been validated through multiple research study to improve critical think in students (Ab et al., 2016; Atay & Karabacak, 2012; Bixler et al., 2015).

Simulation. Simulation has been gaining popularity in various fields of healthcare education as an effective pedagogy (Gibbs, 2015). However, the application of this learning strategy has been limited in sonography. A simulator is a teaching tool that allows students to engage actively in the learning process in a safe and non-learning environment that closely resembles the reality with the educator acting as a facilitator of the learning process. As such, simulators facilitate the acquisition of skills by allowing students to apply their theoretical knowledge in a setting similar to the real clinical situation (Amini, Stolz, Hernandez, Gaskin, Baker, Sanders, & Adhikari, 2016).

Gibbs (2015) evaluated the use of simulation as a pedagogic approach that may be integrated into sonography training to enhance the development of critical thinking and reasoning skills in student sonographers. The qualitative study employed interviews to explore the experiences of 25 first-year sonography students who had interacted with an ultrasound simulator as well as the perceptions of the educators to evaluate the effectiveness of ultrasound simulators in supporting sonography education. The results of the study indicated that simulators were effective in providing a positive learning environment to sonography students in a classroom setting that facilitated the development of critical thinking skills among the students. In addition, the study established that simulators assist in reinforcing the theoretical concepts that relate to sonography, which would be difficult to assimilate in a classroom by providing opportunities to practice skills in a safe and controlled environment. Consequently, it raised the

confidence levels of students and their capability to critically think and reason while assisting in achieving fitness to practice and improving patient safety.

Most of the curricula in sonography are designed to teach students the basics of ultrasound (Amini et al., 2016). However, few of these curricula focus on the development of critical thinking and problem-solving skills. The researchers conducted a quantitative study using a one group posttest-only design to explore the impact of the utilization of a theme-based ultrasound session using a simulated model for the management of a hypotensive patient on the critical problem-solving skills of students. The study was administered to third-year medical students, and their knowledge was assessed through questionnaires after the end of the session and again at three months after the workshop (Amini et al., 2016). Findings indicated that the students demonstrated high levels of knowledge and confidence in performing ultrasound tests and diagnosis of different hypotension clinical scenarios at the end of the session and three months later (Amini et al., 2016).

Baker, Willey, and Mitchell (2011) explored the use of an Objective Structured Clinical Examination (OSCE) among diagnostic medical sonography students to evaluate its effectiveness in assessing their technical and analytic skills and clinical competence in scanning and image analysis. OSCE evaluates the clinical competence by using a multidimensional practical evaluation of clinical skills whereby students rotate through a series of stations while performing specific clinical tasks. Each student is observed and assessed by using a standardized checklist. According to the researchers, the main goal of sonography education is to develop competent sonographers. In theory, this quantitative study should be a reliable assessment of the students' clinical performance and competence. However, the evaluation tools used to assess their clinical performance and competence were unreliable for lack of controlled variables. As

such, it is impossible to appraise whether the students possess the required clinical skills, including critical thinking and reasoning skills, upon graduation.

There were 15 first-year students and 10 second-year students in the study conducted by Baker et al. (2011) using OSCE to include clearly delineated tasks, which included simulated the activities in a clinical setting including obtaining a detailed and relevant history (Baker et al., 2011). Students were tasked with identifying the problem of the patient and coming up with a likely diagnosis collectively from the clinical history, identification of the appropriate diagnostic approaches uses, and investigating the results. The findings of the study revealed that OSCE for sonography students played an integral role in evaluating their technical and interpretive proficiency skills. Besides, it provided valuable insights into the progress of the technological and interpretive competence of sonography students between the first-year and second-year students, as indicated by the average scores between the two groups of students.

Monash University implemented a program for developing the critical thinking and reasoning skills of their radiography students. The program was based on the course model and Dewey's and Schön's theories. Schön (1983) emphasized on technical rationality, which blends with the technical aspect of health science practitioners. Schön (1983) posited that technical rationality requires healthcare practitioners to be instrumental in solving problems. The practitioner integrates theory with thinking and reasoning to achieve the best technical solutions (Schön, 2016). The study evaluated the different activities that promote critical thinking and reasoning, but McInerney and Baird (2016) reported only three. Activities include writing of a report, online platform, and professional learning development contract.

Students used reflective skills when writing a report, which encompasses the clinical decision process, technical skills, and interpretation of the final radiographic image. The online

platform provides real cases, which require the students to analyze, interpret, and articulate their conclusion (McInerney & Baird, 2016). The third teaching tool is a professional learning development contract, which is modeled after Benner (1994) in nursing education. The contract requires the students to complete in-depth case studies involving patients and students' professional experience in the hospital (McInerney & Baird, 2016). The study was a mixed-method involving surveys to measure the activities. McInerney and Baird (2016) contended that the study was subjective as the surveys measured the perception of the students about these activities. Overall, the study had a positive outcome with the students reporting confidence in their critical thinking skills in a clinical setting.

Methodological issues. Quantitative research was the most applied methodology in the study of the effect of teaching strategies in sonography and related fields at improving student's critical thinking and reasoning skills. Most of these studies used pretest-posttest research designs to evaluate the impact of these strategies. As such, the critical thinking and reasoning skills of the students were measured before and after the implementation of the teaching tool. A comparison of pretest and posttest scores provided an insight into the effectiveness of the teaching tool at improving the critical thinking and reasoning skills of students. The experimental designs that were used included a single group posttest-only design, single group pretest-posttest design, and a pretest-posttest design with an experimental group and a control group.

Amini et al. (2016) employed the one group posttest-only design, also referred to as one-shot case study, in their study. In such a research design, a sample of participants are exposed to treatment, and then the dependent variable is measured once and only after the intervention. The design does not have a pretest or a control group. The study employed questionnaires to evaluate the levels of knowledge after the administration of theme-based ultrasound sessions.

However, it was impossible to assess whether there was an improvement in critical thinking and problem-solving skills since there were no baseline scores with which to make comparisons. Thus, it is not possible to make comparisons to gain an insight into what is the effect in the absence of the treatment. As such, it was difficult to draw concrete conclusions due to lack of internal validity (Marlow, 2010). In this case, it is not possible to conclude that variations in the dependent variable are caused by the treatment (independent variable). The causation of the variation may be due to other variables other than the treatment. In addition, it is impossible to tell variations that occur as a result of the passage of time, such as growing of participants in terms of experience with time, among others.

There are also threats such as reactivity and selections bias to external validity, in that there may be other factors in play affecting the dependent variable thereby impacting on the generalizability of the results (Cohen, Manion, & Morrison, 2017). Besides, the ability to generalize the findings is limited because there is a lack of a random sample and a pretest; hence, it is impossible to determine how typical are the participants (Marlow, 2010). This limitation may be overcome by employing a pretest to establish the skills of the students before the implementation of the treatment. In addition, a standardized test should be employed to evaluate their clinical skills, as proposed by Baker et al. (2011).

A single group pretest-posttest design was employed Bixler et al. (2015). In this case, the dependent variable is measured twice, before and after applying the experimental treatment, allowing for comparison between the pretest and posttest scores. Data analysis in this study was performed using the SPSS software. The differences in the pre-intervention and post-intervention were analyzed using the paired *t* test and using a *p* value of 0.05 in establishing whether there was a significant statistical difference between the two groups. However, the design also presents

threats to internal validity concerning the inability to differentiate variation on the dependent variable caused by the passage of time. Therefore, the design should be employed when the time interval is short (Marlow, 2010). Data analysis, similar to the one used in the study, will be used in determining whether there is a statistical difference between the pretest and posttest scores of both groups.

In addition, there is a threat of instrumentation in which there may be a change in the scores used by the measuring instruments between the pretest and posttest. Therefore, it is crucial to use measuring instruments whose reliability to provide standardized scores have been validated through research. For instance, the reliability California Critical Thinking Skills Test (CCTST) employed by Bixler et al. (2015) and the California Critical Thinking Disposition Inventory (CCTDI) by Atay and Karabacak (2011) had been studied by various scholars (Bixler et al., 2015). The design is appropriate when it is not feasible to have a comparison group.

However, like one group posttest-only design, the design poses threats to internal validity and external validity since it is impossible to tell whether the variations on the dependent variable have resulted from changes over time because of the lack of a comparison group. Variations in the instrumentation may also have occurred in the first and second administrations, which may affect the results (Marlow, 2010).

The inclusion of a control group in the experimental design significantly increases the internal validity of the design. Atay and Karabacak (2012) employed such a research design to evaluate the impact of concept mapping on clinical thinking dispositions. In such a design, participants may be randomly assigned to the treatment group and control group, thereby distributing the characteristics between the two groups. Data analysis was carried out using the SPSS software. The pretest and posttest scores between the experimental and control group were

compared using the *t*-test. The differences between scores of the two groups can be attributed to the treatment rather than possible differences between the groups before the treatment. This method will be adopted for this study

Pretests assist in establishing whether there is a difference between the characteristics of the experimental and control group, which may affect the results (Marlow, 2010). Thus, the design is appropriate in the evaluation of the impact of the teaching strategies on critical thinking and reasoning skills in students. However, ethical issues and the nature of the study may limit the random assignment of participants to the two groups.

The use of qualitative interviewing in assessing the impact of learning strategies on critical thinking and reasoning skills of students also employed by researchers as revealed in the review literature. Qualitative interviews are an effective method through which a participant can obtain reliable information and views from participants. The use of an interview guide during the conduct of the interview provides a useful framework for an informal conversation between the researcher and participants, which directs the interviews and guides the analysis (Marlow, 2010).

Methodology research. The methodology for the current study is a pretest posttest quasi-experimental design with an intervention and control group. Quasi-experimental designs are used to test causal hypotheses, particularly on whether a treatment or intervention achieves its objectives (White & Sabarwal, 2014). According to Williams (2007), the quasi-experimental design allows the researcher to assign participants to the control group and the experimental group. The quasi-experimental method facilitates the establishment of a comparison group that is close to that of the intervention group in terms of baseline characteristics. As such, it is possible to capture the outcomes that would have resulted without the intervention applied to the experimental group. The quasi-experimental design has various strengths. The method facilitates

the investigation of cause-effect and is suitable in situations where it is impossible or inappropriate to conduct a true experimental design (White & Sabarwal, 2014). For instance, the method is appropriate where the researcher cannot randomly assign participants to control or experimental group for ethical or other reasons. However, the method presents various limitations, as well. According to Aussems, Boomsma, and Snijders (2011), the lack of random assignment of participants to the intervention and control group makes it difficult to establish proper causal inferences and threatens the internal validity of the study. In addition, the method requires a large sample size to allow conclusive determination of the effect of the intervention (Aussems et al., 2011).

Synthesis of Research Findings

The studies reviewed in this study can be categorized into two broad groups. The first group comprises of studies that evaluated the effectiveness of the scientific method at improving critical thinking and reasoning skills of students. The other group comprises studies that evaluated other methods of teaching critical thinking and reasoning skills. This group is subdivided into those studies that explored the effectiveness of use simulations and those that studied concept mapping.

The scientific method model has not been sufficiently researched since Baun (2004) proposed it. Only one study in the review of literature falls under this category. The study by Foster and Lemus (2015) investigated the effectiveness of the scientific method at enhancing the critical thinking skills of students studying astrobology. The study first established the use and level of critical thinking of students through a survey before the application of the scientific method of inquiry. The results indicated that a majority of the students had regularly used their critical thinking skills in their coursework.

However, most of the students were not comfortable in applying their critical thinking skills to practice in a professional setting, indicating the student's perception of low skill levels. The scientific method was implemented, and a survey was carried out after the exercise. The results indicated that the scientific method was effective in building the students' critical thinking skills and increased their confidence in applying their skills in professional practice. The findings of this study demonstrate that the scientific method enhances critical thinking and reasoning skills and, as such, may be applied in other fields.

Other teaching methods for improving critical thinking and reasoning skills among students in the medical field were explored. The pedagogical approaches examined in the literature review include concept modeling and simulations. Concept mapping has been widely studied for teaching critical thinking skills among students is concept mapping. Three studies explored concept mapping as a pedagogical approach to the teaching of medical students. One of the studies was an extensive review of the past studies that had investigated concept mapping. The other two studies studied concept mapping as an intervention for improving critical thinking skills. The review established inconsistent findings regarding the effectiveness of concept mapping as a teaching method for teaching critical thinking skills. The study by Latif et al. (2016) established that most of the studies had indicated concept mapping as an efficient method for developing critical thinking skills.

Other studies indicated that concept mapping was an effective tool for enhancing learning, organizing, and representing knowledge in a way that allowed a better understanding, but did not improve the critical thinking skills of students. Inconsistent results were also established by two studies that used an experimental design. The studies involved testing the critical thinking skills of students before applying concept mapping and again after its

implementation. The study by Atay and Karabacak (2012) found that concept mapping was an effective tool towards improving the critical thinking of the students. A study by Bixler et al. (2015), on the other hand, established no significant differences in the critical thinking skills of students after the implementation of concept mapping. These inconsistent results indicate the need for further research to establish the extent to which the method improves critical thinking and reasoning skills in students.

Simulations are another method that has been used in the teaching of critical thinking and reasoning skills among students. Two studies investigated the impact of this pedagogical approach on improving critical thinking skills. The studies by Gibbs (2015) and Amini et al. (2016) established that the simulators were effective in providing a learning opportunity in a classroom setting that allowed students to acquire psychomotor skills and develop their critical thinking skills. In addition, simulations increased the confidence of students in applying these skills in a clinical situation. However, the studies used a qualitative methodology that utilized purposeful sampling, thereby limiting the generalizability of results to the entire population. The method may be effective in improving critical thinking skills by offering an environment that students can use to think and make deductions critically. However, there is a need for further research to establish the effectiveness of simulations in improving critical thinking skills.

The review of the literature established that their various methods for teaching critical thinking and reasoning skills. However, these methods do not generate measurable outcomes, or studies on these teaching methods generate inconsistent results. As such, there is a need for the adoption of a more effective pedagogical approach for teaching thinking and reasoning skills among students taking health-related professions, especially among students taking diagnostic medical sonography. Baun (2004) and Penny and Zachariason (2015) indicated that the scientific

method might be effective in developing these skills as it provides a systematic process that leads to critical thinking and reasoning skills. The study by Foster and Lemus (2015) showed the scientific method assisted in the building of critical thinking skills. However, the study involved students in astrobiology, and thus there is a need to establish its applicability and effectiveness in a health-related profession, particularly among diagnostic medical sonography since they require clinical thinking and reasoning skills to interpret sonographic images.

The research design employed for the study on the effect of the scientific method on critical thinking skills is quasi-experimental with a pretest and posttest treatment and control group. The quasi-experimental research design was adopted in this study since it is effective in the testing of the causal effect. The research design is not a true experiment as not all elements are controlled, and what works with this study group of students may not apply to a different group of students (Spickard, 2017). In addition, it is appropriate for conducting research that requires the evaluation of the impact of an intervention by establishing a comparison group that is close to the experimental group in terms of baseline characteristics (White & Sabarwal, 2014). The study includes second-year students enrolled in a diagnostic medical sonography program at a university. The second-year students in both groups will have received the same instruction in their prior first-year laboratory setting, which does not use the scientific method. The second-year students in the experimental group will have the scientific method introduced in the critical thinking course. Comparison analysis of the critical thinking and reasoning skills quantitative design will be evaluated between the two groups. The control group is then used to evaluate the effect that would result from a lack of implementation of the intervention. The difference in the results between the control group and the experimental group is taken to have been due to the treatment (White & Sabarwal, 2014).

A quantitative research design is the most appropriate for this study, as the data collected to answer the research questions are numerical. According to Williams (2007), a quantitative research approach is appropriate for studies that seek to validate, establish, or confirm relationships between variables as well as derive generalizations. The Health Science Reasoning Test by Insight Assessments is utilized to gather a baseline and then confirm an improvement in the skill sets of the student groups. The inherent ability of the students can influence the examination (Facione, 2008). Questions in the Health Science Reasoning Test (HSRT) are based within the context of health care situations but have no bias of specialized knowledge. The domains designed to be tested by the Delphi group include analysis, evaluation, explanation, inference, and interpretation (Facione et al., 2010). The HSRT was found to demonstrate validity in a 2004–2005 validation study of 444 college-level students enrolled in health science professional programs in the content, construct, and the criterion (Facione et al., 2010). The reliability measures of the HSRT are reported Kuder- Richardson-20 (KR-20) of .81 for the total score and KR-20 ranging from .52 to .77 for the subscores (Facione et al., 2010).

Kuder-Richardson 20 is a statistical method used to determine reliability by calculating the number of items, the mean, and the standard deviation. Analysis at zero equates to no reliability, and the closer to one, the more reliability (Mackey, Gass, 2015). The selection of the HSRT was chosen as the instrument for data collection in this study based on the identified critical thinking and reasoning skills identified by Baun (2004) and Penny and Zachariason (2015) specifically for diagnostic medical sonography students. The HSRT is designed for health science professionals in college-level programs to measure critical thinking (Insight Assessments).

Critique of Previous Research

Results from analyzing the assessments of three classes between 2010 and 2012 who underwent the scientific method exercise in the study by Foster and Lemus (2015) indicated positive findings. The number of participants or the duration for which the scientific method was applied was not highlighted in the report. However, the percentages of the responses from the students are given. The data from the study showed that the number of students who used their critical thinking skills in the course work before undergoing the scientific method was high. The percentage of students who reported using these skills regularly was 68% to 70%, while those who occasionally used their critical thinking skills were between 15% and 20%. The percentage of students who rarely used these skills was between 13% and 15%. When the students were asked about their confidence in applying these skills into professional practice, only 30% to 40% of students indicated they would.

The postsurvey results after the implementation of the scientific exercise indicated that the exercise was effective at improving their critical thinking skills according to student responses. The findings indicated that 68% to 74% of the students reported improvement in critical thinking skills, while 22% to 24% were not sure. Only 4% to 9% indicated that scientific method exercise was not useful. Concerning the application of critical thinking skills in a professional setting, the percentage of the students who reported that they felt confident to apply their skills in such settings was 50% to 61%, while 38% to 41% were not sure. Only 9% indicated they would not.

Foster and Lemus (2015) asserted that the results indicated that the scientific method of inquiry was effective at improving the critical thinking skills of the students. The figures show that the percentage of the students who felt that their critical skills were high and those who felt

confident in applying critical thinking skills substantially increased. As such, the argument put forward by the researchers is credible. Foster and Lemus (2015) further argued that the inclusion of scientific method of inquiry in modules would assist in improving the learning experience of students, increase their critical thinking skills, and prepare them for practice. Foster and Lemus's (2015) study highlights the need for inclusion of scientific method in the learning of students in fields in which critical thinking is of utmost importance.

The study by Atay and Karabacak (2012) evaluates whether concept mapping influenced the critical thinking skills of 80 students randomly assigned to the experimental group and control group. Descriptive statistics of the two groups indicated that the experimental group comprised of 53.7% first-year students, while their percentage in the control group had 62.5%. As there might be differences in critical thinking between first-year and second-year students, a pretest assessment was necessary. The pretest critical thinking disposition mean scores were 220 for the experimental group while that for the control group was 221. In addition, the t value ($t = 0.37, p > 0.05$) indicated that the differences between the pretest scores were not statistically significant.

The t -test value confirms that the pretest mean scores of the two groups were not significantly different. The indication is that the critical thinking dispositions of students in the two groups were similar, and thus any differences in the posttest scores would be a result of the intervention. After the intervention, the mean scores for critical thinking disposition was 247 for the experimental group, while that for the control group was 225. In addition, the t test ($t = 5.37, p < 0.05$) established significant statistical differences between the posttest mean scores. In light of these findings, concept mapping was critical in enhancing the critical thinking disposition. As

such, the conclusion that concept mapping was significant at improving the critical thinking disposition of students is grounded.

The study by Bixler et al. (2015) had 27 participants who completed a pretest before the course applying concept mapping and a post-course. Both pretest and post-CCTST scores were significantly high, indicating that the students had superior critical thinking skills. The pretest overall CCTST score was 83.9%, while the score after the intervention was 85.6%. As such, the difference between the two values was not significant. Thus, the assertion by Bixler, Brown, Way, Ledford, and Mahan (2015) that concept mapping did not have a significant impact on the CCTST scores was justified. Bixler et al. (2015) pointed out that the potential reason for the lack of significant improvement in CCTST scores was due to high baseline scores before the intervention was implemented. The study by Bixler et al. (2015) differs in results from the previous research conducted on concept mapping by Ab et al. (2016), and Atay and Karabacak (2012) where there was an earlier intervention in the students learning the process.

The ability to detect an increase in the CCTST scores was limited in the study by (Bixler et al., 2015). The high scores achieved by the participants for critical thinking indicated that the students had strong critical skills, and thus, the intervention had little or no significant impact. In addition, the study used a small sample size that would have made it difficult to detect a small statistical difference in the CCTST score. Furthermore, the short duration for which the intervention was applied may not have been sufficient to have a significant impact on critical thinking skills. Bixler et al. (2015) implied that there is a possibility that concept mapping may not sufficiently increase critical thinking skills by itself. However, this is an area that needs further research to articulate the effectiveness of concept mapping as an intervention for improving critical thinking skills.

Simulation of clinical cases could add validity to instruction and application of the scientific method in developing critical thinking skills in diagnostic medical sonography students. The study by Gibbs (2015) used a qualitative method to obtain the perception of 25 first-year sonography students who had interacted with a MedaPhor® ScanTrainer ultrasound simulator. The sample represented 47% of the students undertaking the Diagnostic Ultrasound Program. The sample was thus representative of the cohort, and thus, the results were credible. In addition, the study gathered the perceptions of 14 educators on the effectiveness of the simulator at preparing the students for clinical practice using interviews. This sample was sufficient to obtain meaningful results. Guest, Bunce, and Johnson (2006) recommended a sample size of 12 participants while conducting qualitative interviews. Thematic analysis of the data revealed that the simulator helped improve critical thinking skills. Considering these findings, Gibbs (2015) asserted that the simulators played a significant role in providing skills and training of students. This argument reflects the results of the finding. However, the researcher used a qualitative methodology that is not generalizable. As such, there is a need for further research to evaluate these findings.

Another strong example of simulation correlating critical thinking skills with the application of technical skills is the study by Amini et al. (2016), which used a qualitative methodology to assess the impact of a simulated model for the management of hypotensive patients. The study used a sample size of 101 participants drawn from third-year students, which were sufficient for generalization of results to the general population. The study employed questionnaires to evaluate the level of knowledge and confidence in performing ultrasound tests and diagnosis of clinical hypotension scenarios. However, the evaluation was done after the implementation of the simulation model. Lack of evaluation of these variables at the baseline

made it impossible to compare and deduce improvements that resulted from the simulation. Though the student performance in the knowledge assessment, average confidence level after the end of the session was high, meaningful conclusions could not be made. The methodology did not produce conclusive results and thus will not be adopted for this study.

Following the path of earlier intervention, McInerney and Baird (2016) to evaluate the activities that improve the critical thinking skills of students used a mixed-method approach with a survey designed in Survey Monkey. The study evaluated these activities on a five-point Likert scale. The study had a sufficient sample size of 101 participants, which improved the credibility of results. The findings indicate that activities scored high on the Likert scale. Thus, the assertion by McInerney and Baird (2016) that the activities were beneficial in improving the critical thinking skills of students were justified. Thus, the correlation of didactic knowledge, clinical information, and technical skills required to complete the examination following the practice of using the scientific method as a required active component of the clinical experience should improve the students' clinical thinking skills.

Critical thinking and reasoning specific to diagnostic medical sonography. Critical thinking concept originated from the early Greek philosophers, the likes of Socrates and Plato (Paul & Elder, 2009). Eventually, critical thinking came to be included as part of academic learning in higher education institutions to allow learners to examine ideas and develop conclusions (Sharp et al., 2013). Critical thinking skills include evaluation, deduction, induction, analysis, and inference. These skills are taught in courses across all health professions. In sonography, critical thinking entails processing and analyzing the information in diagnostic images (Baun, 2004). The scientific method has been proposed as an effective method of developing critical thinking and reasoning skills.

Penny and Zachariason (2015) developed the SRM as a framework to simplify the application of the scientific method in the development of critical thinking and reasoning skills among sonography students. The method involves five steps, which include the investigation of history, making of hypotheses, analyzing with sonography, the gathering of all sonographic findings, and evaluation for connections (Penny & Zachariason, 2015). The application of the scientific method of inquiry is useful in furnishing students with critical thinking skills (Foster & Lemus, 2015). However, the scientific method developed by Penny and Zachariason,(2015) has not been studied to evaluate its effectiveness at developing critical thinking and reasoning skills. This scientific method model is the impetus of this study. The conceptual framework of the study is the constructivist theory, which calls for the active participation of the student in the learning process (Singh & Rajput, 2013).

Various methods of teaching critical thinking have been studied in the past, including concept mapping and the use of simulations. Concept mapping was found to be effective at improving the critical thinking skills of students (Aay & Karabacak, 2011; Latif, Mohamed, Dahlan, & Nor, 2016). However, a study by Bixler et al. (2015) did not establish the significant impact of concept mapping on critical thinking skills. Studies conducted by Amini et al. (2016) and Gibbs (2015) established that the use of simulations was effective at improving the critical thinking of students. The methodology of these studies, the sample size, duration, and the level of students in the degree program may have influenced the results.

Studies that used qualitative design present difficulties in making generalizations. As such, a qualitative design will be avoided in this study. The review of studies established that quantitative studies using a pretest posttest experimental and control group design were the most effective method while evaluating the effectiveness of the methods of teaching critical thinking

and reasoning skills (Ab et al., 2016; Atay & Karabacak, 2012; Bixler et al., 2015; Gibbs, 2015). In addition, the participants should include students in lower levels in the degree program (freshman and sophomore students) who do not have strong critical thinking skills to be able to detect the impact of the pedagogical approaches of teaching critical thinking and reasoning skills.

Summary

The decisions made by medical care professionals have significant consequences on the patients. Poor decisions may have significant consequences on the safety of the patients. Clinical thinking and reasoning skills are thus of utmost importance for medical students. Developing these skills among students reduces cases of poor treatment (Facione & Facione, 2008). Critical thinking and reasoning skills are essential skills that sonography students must learn in the diagnostic medical sonography program. The literature review covered the history of critical thinking and the pedagogical approaches that are used in health programs to develop critical thinking skills.

Chapter 2 covered a review of relevant literature in the domain of critical thinking, including the history of critical thinking, the significance of critical thinking in health sciences, the teaching of critical thinking, and the models of teaching critical thinking skills. Covered as well includes the conceptual framework informing the study, review of research literature and methodological literature, consideration of methodological issues, synthesis of research findings, and critique of previous research. Chapter 3 will cover the methodology that will be employed for this study. Described in Chapter 3 is the purpose of the study, research questions, and hypotheses, research design that the target population, and the sample size and technique used in the recruiting participants. In addition, detailed are the instruments for gathering data, data collection methods, the operational definition of variables, and analysis procedures. Lastly, the

study will explain the study limitations and delimitations, internal and external validity, expected findings, and ethical issues in the study.

Chapter 3: Methodology

Introduction

Research has established that there is a need to improve the methodology used in teaching critical thinking and reasoning skills in health education programs to reduce the errors that result from poorly reasoned clinical decisions (Sharp, Reynolds, & Brooks, 2013). Most forms of instruction in allied health sciences concentrate mostly on the application of practice at the expense of critical thinking and reasoning skills (Sharp, Reynolds, & Brooks, 2013). Educators assume that students will learn critical thinking and reasoning skills through experience in a clinical setting. However, intentional early development of critical thinking and reasoning skills among diagnostic medical sonography students is essential to enhance care (Penny & Zachariason, 2015).

These skills are pertinent for accurate interpretation of a patient's clinical history and sonographic images during diagnosis, which has a direct effect on the quality of care and consequently results in better outcomes for patients (Penny & Zachariason, 2015). Sonography education programs are required to provide instruction that will facilitate the development of critical thinking and reasoning skills among students. The concern is that the instructional methods used in diagnostic medical sonography programs do not sufficiently develop critical thinking and reasoning skills among this population of students (Penny & Zachariason, 2015).

Baun (2004) developed the scientific method as an approach to teaching and encouraging the development of clinical thinking and reasoning skills of students in sonography programs. Penny and Zachariason (2015) further expanded the scientific method proposed by Baun (2004) by developing a model to assist in bridging the gap between academic knowledge and clinical practice among students. The model, referred to as the SRM, is a framework for a five-step

process based on the scientific method, which combines critical thinking and reasoning skills to facilitate the development of these skills among students. The SRM provides a simplified evaluation of the scientific method through five steps, which include investigation of history, making of hypotheses, analyzing with sonography, gathering sonographic, and evaluating for connections. The constructivist theory forms the basis for this study, along with the concept of personalized learning, actively using critical thinking and reasoning skills to analyze and interpret the information acquired (McGarrity, 2013; Zmuda et al., 2015). To use the scientific method, the students must become active participants in their learning along with reflexivity, which is encouraged in the constructivist theory (Sing & Rajput, 2013). The students begin to develop their awareness of their critical thinking process through reflexivity (McGarrity, 2013; Singh & Rajput, 2013; Zmuda et al., 2015). Reflexivity is the relationship between knowledge (classroom learning) and clinical practice by developing a methodological means of detecting information and bridging the classroom to the clinical setting (Charmaz, 2016). In diagnostic medical sonography, the students gather information from the patients and the sonographic examination and perform their analyses at the individual level (Charmaz, 2016). The scientific method has never been studied to establish its effectiveness towards developing critical thinking and reasoning skills among sonography students. The study seeks to address this research gap.

The main goal of this study is to investigate the validity of the scientific method as an approach to teaching critical thinking and reasoning skills evaluating its impact on developing these skills in students enrolled in the diagnostic medical sonography program at the university. The level of critical thinking and reasoning skills of the students undertaking the diagnostic medical sonography students will be assessed. The administration of a posttest will assess levels

of critical thinking and reasoning skills after receiving the instruction using the scientific method in teaching these skills.

Chapter 3 contains a description of the methodology that will be used in this study to carry out the investigation. The methodology is described along with the purpose of the study, research questions, and hypotheses. An explanation of the research design adopted for this study, the target population, sample size, and the technique used in participant recruitment is also discussed. In addition, the chapter details the data collection instruments, methods, the operational definition of variables, and data analysis procedures. Highlighted are the limitations and delimitations, internal and external validity, expected findings, and ethical issues for the study.

Purpose of the Study

The purpose of this quasi-experimental study was to determine the effect of scientific method instruction in developing critical thinking and reasoning skills required for accurate interpretation of sonographic images among diagnostic medical sonography students enrolled in a bachelor degree program at the university. The study examined the effectiveness of this instructional teaching model in bridging the academic theory into clinical practice; it also assessed the effectiveness of the scientific method as a methodology that educators may use to improve the student's ability to think critically and reason in the clinical environment.

Diagnostic medical sonography programs are taught at different levels, which include certificate and Associate of Science (AS) degrees offered at community colleges, certificates at hospital-based programs, and the Bachelor of Science (BS) degree sponsored by regionally accredited universities. Bachelor degree programs are required to teach students not just theory and protocols for sonography examinations; university programs in medical imaging sciences

must provide instruction that develops critical thinking and reasoning skills and encourage the development of these skills among students (McInerney & Baird, 2016).

Research Questions

The study evaluated the effect of instruction using the scientific method in developing critical thinking and reasoning skills among diagnostic medical sonography students. The study is guided by the following research questions:

1. How significant is teaching diagnostic medical sonography students the scientific method to improve their critical thinking and reasoning skills?
2. How significant is the difference in critical thinking and reasoning skills among diagnostic medical sonography students who receive instruction using the scientific method compared to those who receive instruction using other methods?

Hypothesis

The hypothesis for the study was developed from the research questions. The hypothesis and the respective null hypothesis are presented below;

H₀: There is no significant difference in the critical thinking and reasoning skills of students who receive instruction using the scientific method and those who receive instruction using the traditional/nonscientific method.

H₁: There is a significant difference in the critical thinking and reasoning skills of students who receive instruction using the scientific method and those who receive instruction using the traditional/nonscientific method.

Research Design

The research design refers to the general plan of approach to the research problem by directing how, when, what, and who of the research. It is the overall strategy used in organizing a

study to generate answers to the research questions. A research design guides the study regarding data collection, measurement, and analysis of data (Gorard, 2013). There are three approaches recognized in the literature that are used to conduct research: quantitative, qualitative, and mixed methods (Castellan, 2010). Quantitative approaches are appropriate for use in studies that require numerical data and seek to establish cause and effect or associations among variables, while the qualitative method is employed for studies that require textual data.

Further, qualitative studies seek to explore and understand the phenomenon from the lived experiences of individuals. On the other hand, mixed methods are used in studies that require both textual and numerical data to answer the research questions (Williams, 2007). A quantitative research design is the most appropriate for this study, as the purpose of the study was to test whether there was a difference in critical thinking skills between sonography students who received critical thinking instruction that utilized the scientific method and those who did not.

The quantitative research approach is suitable for studies that seek to validate, establish, or confirm relationships between variables as well as derive generalizations (Williams, 2007). Castellan (2010) posited that quantitative research is used when the study seeks to test hypotheses, predict and control, validate, establish facts, describe statistically, and show relationships between variables. The quantitative design is thus the most appropriate design for this study since it aims at examining the effect of instruction using the scientific method on the development of critical thinking and reasoning skills among diagnostic medical sonography students.

Quantitative research employs predetermined instruments in the collection of data (Williams, 2007). Various strategies of inquiry are used in quantitative research, such as surveys

and experimental designs (Creswell, 2016). Survey design seeks to provide numeric or quantitative descriptions of perspectives, attitudes, or trends in a population through studying a sample of the population. On the other hand, experimental designs are employed to establish whether a specific treatment impacts an outcome.

In such experimental studies, the treatment is provided to one group and withheld from another group, followed by a comparison of outcomes between the two groups (Creswell, 2016). An experimental research design is the most appropriate for this study since it entails the investigation of the outcomes of the use of the scientific method as an intervention or treatment (Creswell, 2016). Experimental research design can either be true experimental or quasi-experimental. True experimental designs involve random assignment of study participants to both treatment and experimental groups, whereas the assignment of participants in quasi-experimental design to the experimental or control group is not random (Williams, 2007).

The research design used in this study is a quasi-experimental with a pretest and posttest treatment for the control and experimental groups. The quasi-experimental research design was adopted in this study for testing the causal effect that used the scientific method of instruction (White & Sabarwal, 2014). In addition, it is appropriate for conducting research that requires the evaluation of the impact of an intervention by establishing a comparison group that is close to the experimental group in terms of baseline characteristics (White & Sabarwal, 2014). A comparison between the groups is then used to evaluate the effect that would result from a lack of implementation of the intervention. The difference in the results between the control group and the comparison group is taken to have been due to the treatment (White & Sabarwal, 2014).

Participants included in the research groups for this dissertation study are second-year sonography students enrolled in the diagnostic medical sonography program at a university. The

control group of students receives instruction using a non–scientific method of instruction during the learning sessions in the sonography laboratory. The scientific method is employed as the instructional model for the experimental students during their learning sessions in the sonographic laboratory. As such, it is impossible to randomly split the participants between the experimental and control groups for a true experimental research design as the students were assigned to the laboratory sections.

White and Sabarwal (2014) asserted that quasi-experimental research designs are employed when the researcher has little control over treatment randomization, and thus, it is not possible to randomly assign individuals to experimental and control groups. Preferably, the researcher selects the participants to include in either group or the study participants are allowed to self-select. For this reason, a quasi-experimental design is adopted due to the nonrandom assignment of participants to experimental and control groups. The control group included only students in a specific laboratory course section, while the experimental group included only the students from another laboratory course section.

Target Population, Sampling Method, and Related Procedures

A population in research is the entire group from which the study seeks to ascertain information from (Banerjee & Chaudhury, 2010). The target population refers to the defined population from which the participants will be recruited. According to Banerjee and Chaudhury (2010), the target population should be well defined to spell out participants to be included and excluded clearly. Sampling refers to the selection of a subsection of a population that represents the target population in the gathering of data on a phenomenon of interest (Marsden & Wright, 2010). A sample is a subset of the general population selected for inclusion in the study that is used in drawing inferences regarding the population.

A sampling-based on the course section of enrollment was used to recruit 12-second-year students for the experimental group and 12 second-year students for the control group. The selection of the study sample is from the diagnostic medical sonography students at a regionally accredited university. There are two groups of sonography students enrolled in the program, each in a different section but both entering their second year and first clinical rotations concurrently. Both groups of students are enrolled in the diagnostic medical sonography program. The students currently are completing diagnostic medical sonography courses in the program with a grade 77% or higher to progress to the second year. The students have completed their first year's didactic and laboratory classes and are in the first clinical internship. There were 24 students enrolled in the diagnostic medical sonography program. Students were selected to take part in the study based on their section number and are placed in the control group or the experimental group. Students in the selection groups met the diagnostic medical sonography program admissions and progression standards with no other qualifiers in place for selection.

Intervention. The intervention is instruction for the experimental group of students in the scientific method. The scientific method will be applied to facilitate the instructional process for the instruction in the form of students documenting case studies in the classroom and clinical setting. Instructional methods are easier discussed than executed. A rephrasing of the scientific method by Penny and Zachariason (2015) simplified and renamed the SRM, which is a five-step process.

Table 1

Comparison of Methodology

Scientific Method (Baun, 2004)	Sonographic Reasoning Method (Penny & Zachariason, 2015)
Observation	Clinical history
Hypotheses	Hypotheses
Data collection	Investigative imaging
Data analysis	Sonographic findings
Conclusion	Clinical Correlation

The students were required to present their selected case studies following the steps of the scientific method in both the oral presentation and written summation of the case study.

Continued use of the scientific method will improve student skills in using critical thinking and reasoning as they apply to clinical practice (Baun, 2004). Continued practice should allow the student to be more aware of the entire clinical process. This information was documented by the information provided in each of the five categories. All presented studies are reviewed based on the final interpretation of the reading physician and pathology reports when present. The data were collected in the form of an evaluation completed by the clinical instructors, which evaluated the student's critical thinking skills (see Appendix A). The evaluation by the clinical preceptors is available for students receiving instruction in the scientific method as well as the students not receiving instruction in the scientific method.

Instrumentation

The critical thinking skills of the participants were measured using the Health Science Reasoning Test (HSRT). The HSRT is a validated critical thinking skill test that was developed by Insight Assessment and is designed to measure the critical thinking skills of professional practitioners in health sciences and students in health sciences educational programs (Cox & McLaughlin, 2014). HSRT is a computer-based 33-item multiple-choice test that evaluates the

critical thinking skills of individuals in the five domains defined by the American Philosophical Association as constructs of critical thinking: analysis, inference, evaluation, induction, and deduction (Cox & McLaughlin, 2014). In addition, the overall critical thinking score is evaluated (Kelsch & Friesner, 2014).

The HSRT was selected to provide objective data, which can quantify the critical thinking skills of the; it is a web-based test but can also be administered using paper format. The categories for the subsets are strong, moderate, and not manifested. The categorical score ranges are shown in Table 2. The exam is not specific to health science knowledge, but the item vignettes are placed in the healthcare setting versus everyday life settings like CCTST (Cox & McLaughlin, 2014).

The test was administered for 50 minutes and can be administered by individuals without prior knowledge in health sciences (Cox & McLaughlin, 2014). Individuals who obtained an overall score of 15 to 20 are considered to have moderate critical thinking abilities, while those who scored 21 to 25 are considered to have strong critical thinking abilities (Facione & Facione, 2013). Scores greater than 26 indicate superior critical thinking skills. Additional scorings for the five subsets are also evaluated with subscale scores greater than five, indicating strong analysis, inference, and evaluation skills while scores above eight indicate strong deduction and induction skills (Facione & Facione, 2013).

Table 2

Categorical Levels of HSRT Scores (Insight Assessment, 2019)

HSRT (33-point version)	Qualitative Interpretation of HSRT Scale Scores			
	Not Manifested (points)	Moderate (points)	Strong (points)	Superior (points)
Overall Score	0–14	12–20	21–25	26–33
Analysis	0–2	3–4	5 or more	N/A
Inference	0–2	3–4	5 or more	N/A
Evaluation	0–2	3–4	5 or more	N/A
Induction	0–4	5–7	8 or more	N/A
Deduction	0–4	5–7	8 or more	N/A

There are limited studies that have evaluated the validity of HSRT. Huhn, Black, Jensen, and Deutch (2011) conducted a study on physical therapy students to evaluate the construct validity of HSRT by assessing whether it could differentiate the critical thinking skills of expert and novice physical therapists. The findings of their study established that HSRT was able to differentiate between novice students and more experienced students based on their clinical thinking skills, thus establishing construct validity. The total overall critical thinking scores were compared with an independent *t* test, and the subsets were evaluated using an ANOVA (Huhn, Black, Jensen & Deutch, 2011). The findings of the study established that HSRT could discriminate between students with expert and novice critical thinking skills. Studies by Cox and McLaughlin (2014), and Kelsch and Friesner (2014) established that the test was reliable in measuring the critical thinking skills and clinical performance of healthcare.

Another study conducted by Sharp, Reynolds, and Brooks (2013) used HSRT to examine the critical thinking of 57 health informatics and allied health students who were graduating from a university located in the southeastern United States. An internal consistency value where $\alpha = 0.85$ was achieved using Cronbach's alpha. The results of the study were within the accepted alpha value of $\alpha = 0.70$ and $\alpha = 1.0$, which indicates that the test has internal consistency.

The critical reasoning and thinking skills are more subjective and thus require a qualitative analysis (Facione & Facione, 2013). The critical reasoning skills of the participants were evaluated using focused questions. The directed focus questions were completed by the clinical preceptors, which assessed the ability of the students to bridge didactic and critical thinking skills in a clinical setting. The focused questions had a numerical ranking that correlates to a percentage score for the student's performance. The focused questions were delivered via the internet through Trajecsystm. Trajecsystm is a cloud-based record-keeping system that provides reports based on student assessment from the evaluation forms (Trajecsystm, 2016). The reporting system meets the standards for accreditation set forth by the Joint Review Committee on Education in Diagnostic Medical Sonography (JRC-DMS; Trajecsystm, 2016).

Data Collection

The first step in the data collection process involved the submission of the application to the Institutional Review Board (IRB) of the university research site for approval to conduct the study. IRB approval was obtained from Concordia University and the university research site. The data collection process began after approval by IRB to proceed with the study, and permission was granted to use the research site. Participation in the study is voluntary, and the course section instructors did not approve the student's participation. Informed consented forms were handed to the student participants and clinical instructors, informing them of the purpose of the study. The informed consent forms informed the study participants that participation was voluntary, and they could withdraw at any time without any consequences. In addition, the student participants were informed that the data gathered on their critical thinking and reasoning skills would be kept confidential and used for research purposes only.

Data collection involved the administration of tests using the HSRT and focused questions determining the critical thinking and reasoning skills of the study participants before and after the delivery of instruction using the scientific method. A pretest was administered to the participants in the control and experimental group at the start of the semester. The HSRT and the focused questions were administered independently at the university's computer testing lab. Prior health science knowledge is not required to administer the HSRT focused questions (Cox & McLaughlin, 2014). The clinical preceptors' (clinical sonographers who instruct the students at the healthcare facility) evaluation of the focused questions were selected from the facilities delivering clinical education, which have an affiliation agreement with the university. A pre and post HSRT test was administered to students. Clinical preceptors evaluated and assessed the focused questions on their assigned students through the Trajecsys™ as part of the posttest evaluation.

The pretest was used to establish the critical thinking and reasoning skills of both the control and experimental group to determine there is a significant statistical difference between the two groups was the baseline data. Group Two students received instruction using the scientific method model throughout the semester, while the Group One students were instructed using other nonscientific models of instruction at the institution. The instruction for both groups was delivered in the university's sonography laboratory. A posttest, which used the HSRT test, was performed at the end of the semester. The data obtained from the HSRT and focused questions were transferred to the researcher's computer for analysis. The data is stored in a password-protected folder to ensure confidentiality.

Operationalization of Variables

Operationalization refers to the process of converting a concept or a variable into a measurable factor (Beaumont, 2009). The measure can take the form of a scale, constant, or variable (Beaumont, 2009). The independent variable for this study is the scientific method model of instruction, while the dependent variables are critical thinking and reasoning skills.

The scientific method involves the student following and writing the information obtained in the five-step process on each sonographic examination the student participated in the clinical experience. The five steps include the investigation of history, making of hypotheses, analyzing with sonography, the gathering of all sonographic findings, and evaluation for connections (Penny & Zachariason, 2015). The student elicits information directly from the patient, and their medical records, laboratory test, and other diagnostic testing related to the examination ordered. Based on the gathered information, the student forms a hypothesis as to what will be imaged during the examination. The student will perform the sonographic examination, gathering all the findings from the imaging. Finally, the student connects the patient history to the sonographic findings, which provide the information for a diagnosis to be made by the physician.

Critical thinking skills in this study will refer to the ability of an individual to apply the regulatory judgment of an issue through analyzing, conceptualizing, evaluating, and synthesizing available information. The critical thinking skills were measured in terms of scores ranging from one to 10 for the five subsets of analysis, inference and evaluation, deduction, and induction. A total of the subsets comprises the overall score for critical thinking skills. Critical reasoning skills are the ability of an individual to apply logic to make sense of an issue based on available evidence in order to establish and verify facts. Numerical scores from the HSRT test used to measure critical reasoning skills range from one to 10. One is the minimal critical reasoning

skills score, and a score of 10 indicates superior critical reasoning skills (Facione & Facione, 2018).

Data Analysis Procedures

Data was analyzed using both descriptive and inferential analysis. More than one statistical assessment was used to show the consistency of the results obtained from a small sample size. A paired *t* test was used with this study as the assumptions of one dependent and one independent variables were met (Laerd Statistics, 2015). The two-tailed paired *t*-test was used to compare the pretest data of both groups (Huhn, Black, Jensen & Deutch, 2011). An ANOVA was used to analyze data from the HSRT and can be used in the social sciences and health care fields. Completion of the checklist to meet the ANOVA assumptions were completed. The analysis of the data from the two sources was conducted independently. The descriptive analysis provided information on demographic distribution, mean, standard deviation. Paired *t* tests were conducted on the pretest and posttest scores of both the experimental and control groups to determine whether the scores are statistically different.

An ANOVA (analysis of variance) was used in this study as it evaluates two or more variables. The ANOVA showed whether the instruction or lack of instruction relates to an improvement of critical thinking skills. The ANOVA allows a comparison of two variables simultaneously (Spickard, 2017). The ANOVA allows for a controlled variable receiving specific instruction versus the group without instruction. These methods established whether the two methods of instruction improved the critical thinking and reasoning skills of the two groups. An ANOVA was performed to determine whether the pretest scores between the two groups are significantly different at the baseline level. A *p* value of < 0.05 is considered statistically significant, meaning the probability of the results occurring by chance is only 5% of the time

(Spickard, 2017). Typically, the results of the analysis are presented in tabular form. The ANOVA test met the assumptions of each group sample is drawn from a normally distributed population of diagnostic medical sonography students with a common variance. Each sample observations and test results from the HSRT are sampled independently of each other.

Limitations and Delimitations of the Research Design

There are various limitations to this study. First, the sample size of the study is relatively small, which limits the ability to arrive at results that are more conclusive. A random selection of the participants to the experimental group and control group is not possible given that the instruction model using the scientific method is delivered to all the second-year students. As such, the critical thinking and reasoning skills may not be similar at the baseline (Beaumont, 2009). Furthermore, results may be specific to the institution and thus not apply to all diagnostic medical sonography programs. Future studies may be necessary to determine whether the results can be generalized to other institutions.

The study also has a number of delimitations. The study participants were recruited from the participants enrolled in the diagnostic medical sonography students program at one university. The sample size was $n = 24$. There were only 12 participants available for inclusion in the control group, and as such only 12 participants included in the experimental group to allow matching of the participants. The study was conducted for one semester.

Internal and External Validity

Internal validity in experimental studies is enhanced through the inclusion of a control group (Marlow, 2010). A control group was used in this study to enhance internal validity. Since the random assignment is not possible, a pretest was used to help establish whether the two groups are comparable at the baseline. In addition, internal validity was improved through the

use of a pretest and posttest for both the experimental and control groups (Marlow, 2010). As such, it was possible to evaluate whether the change in the level of critical thinking and reasoning skills of students resulted from the instruction delivered.

Creswell (2016) describes the quantitative method using an existing instrument that establishes the validity of data in quantitative research. According to Creswell (2016), the instrument needs to have the ability to draw meaningful scores from the information measured. In addition, the reliability of the instruments to measure what they are supposed to measure was validated through other studies. External validity is improved through the use of validated instruments in the process of data collection. The study employs validated standardized tests that have been employed in previous studies to measure critical thinking skills. Sharp, Reynolds, and Brooks (2013) evaluated the internal validity of the five scales that determined the overall HSRT score and obtained a Cronbach alpha value of $\alpha = .85$. A Cronbach alpha value between $\alpha = .70$ and $\alpha = .95$ is considered to be an acceptable measure of the validity of an instrument (Tavakol & Dennick, 2011).

Expected Findings

It is expected that the critical thinking and reasoning skills of students receiving instruction using the scientific method were significantly improved by the end of the semester. In addition, the critical thinking and reasoning abilities of the students that received instruction using the nonscientific method may improve. However, it is expected that the differences between the two groups of students at the end of the semester were statistically different.

Ethical Issues in the Study

Approval for the study was received from Concordia University's institutional research review board (IRB). An informed consent form was provided to participants prior to beginning

the study, informing them of the purpose of the study, how it will be conducted, and the potential benefits. Participation in the study was voluntary, and participants were free to withdraw from the study at any time. Participants were provided the method of withdrawing from the study along with contact information. The study does not present any risks to the participants. The researcher conducted the instruction, but in order to remove bias, the HSRT objective test was administered as both the pre and posttest. The directed focus questions were not conducted by the researcher, but the clinical preceptors at the clinical facilities answered those questions online (see Appendix A). The researcher maintained the confidentiality of the identity of the participants and all the data gathered from the HSRT and focused questions. All the data from the tests are stored in a password-protected folder on the researcher's computer. The signed consent forms were electronically obtained when clicking to the Insight Assessment link to take the HSRT. In addition, the names of the participants were not used in the presentation of the results or the writing of the report.

Summary

Sonography education programs are required to provide instruction that facilitates the development of critical thinking and reasoning skills (Penny & Zachariason, 2015). However, the methods of instruction that are currently used do not sufficiently develop these skills among students. The purpose of the study was to evaluate the effectiveness of the instruction model based on the scientific method developed by Baun (2004) and expanded by Penny and Zachariason (2015) in developing critical thinking and reasoning skills. The purpose of the study was to investigate if instruction delivered using the scientific method improves critical thinking and reasoning skills of students and whether there are significant differences in the skills of

learners as a result of using the two models of instruction. The two models of instruction are evaluated in the study, one using the scientific method and the other traditional approaches.

A quantitative quasi-experimental research design with a pretest and posttest was employed in this study. The design was selected because it was not possible to assign the participants to experimental and control groups randomly (White & Sabarwal, 2014). The target population is the second-year students enrolled in the diagnostic medical sonography program at the university. The sample size of the study is 24, with 12 participants in each group. All 12 Group One students included in the study and were assigned to the control group. All 12 Group Two students included in the study and were assigned to the treatment group. The instruments used in this study are the Health Science Reasoning Test (HSRT) to test the clinical thinking skills and focused questions delivered through Trajecsys™. HSRT is reliable in measuring the critical thinking skills of students by various studies (Cox & McLaughlin, 2014; Kelsch & Friesner, 2014).

The framework for the collection of data for the study was covered in Chapter 3. The study compared and contrasted the two study groups with one group receiving explicated instructions while the second group is without instruction in the scientific method for critical thinking and reasoning skills. Presented in Chapter 4 is the analysis of the data generated from this study regarding instruction using the scientific method to improve critical thinking and reasoning skills in diagnostic medical sonography students. Interpretation of the research study analysis from Chapter 4 is completed in Chapter 5.

Chapter 4: Data Analysis and Results

Introduction

The purpose of this quasi-experimental research was to examine the effect of using the scientific method on diagnostic medical sonography student's critical thinking and reasoning skills in the clinical setting. The implementation of using the scientific method in the clinical setting was introduced into the curriculum, with an evaluation of the success in improving critical thinking and reasoning in the student population. Although the Health Science Reasoning Test (HSRT) can measure the changes in the student performance in critical thinking and reasoning, it does not ensure all components of clinical skills are measured.

Insight Assessments offers the Health Science Reasoning Test targeting only the cognitive aspects and the definition of critical thinking by the Delphi Report from 1990. The exam was developed for the healthcare professional preparation programs, although knowledge of health care is not required (Insight Assessment, 2018). The HSRT has been applied to health care professions such as medical, dental, physical therapy, and nursing. A study with physical therapy students tested the construct validity of the HSRT by evaluating the test's ability to separate novice and expert physical therapists. Although while evaluating the total score for the exam, the student experts scored higher than the novice students evaluated (Huhn, Black, Jensen, & Deutsch, 2011). A study evaluating critical thinking abilities in undergraduate nursing students showed that the average HSRT score increased with each year of nursing education (Hunger et al., 2014).

This chapter provides a summary of the methodology and results of this study. The two critical questions answered through the research study are:

1. How significant is teaching diagnostic medical sonography students the scientific method in improving their critical thinking and reasoning skills?

The null hypothesis for research question one is:

H₁₀: There is no significant difference in the critical thinking and reasoning scores of the students after receiving instruction using the scientific method.

2. How significant is the difference in critical thinking and reasoning skills among diagnostic medical sonography students who receive instruction using the scientific method compared to those who receive instruction using other methods.

The null hypothesis for research question two is:

H₂₀: There is no significant difference in the critical thinking and reasoning skills of students receiving instruction using the scientific method compared to those who receive instruction using other methods.

Description of the Sample

This study targets students admitted to the diagnostic medical sonography program at a private university in the northeast United States. Students are admitted to the program based on the university admission process, and student demographics were not collected. The collection of these demographics would allow the principal researcher to match individuals to their scores. The pretest and posttest were administered online through Insight Assessments through an online testing format located on their website. Peter Facione, who led the Delphi Research Project, which established the definition of critical thinking and the assessment of the cognitive skills (Insight Assessments, 2019), established Insight Assessments. Students were provided a written invitation to participate, a consent form for the research study, which was implied upon accessing the HSRT. The consent form clearly makes known to the students that participation

was voluntary, anonymous, and would have no impact on their course grade. Two groups of 12 students are included in the study. The students in Group One, who are in the second year of their professional phase of education in diagnostic medical sonography, did not undergo instruction in the scientific method. Group Two students were also in the second year of their professional phase of education and were provided with systematic instruction in the scientific method. The students in each group completed the pretest at the beginning of their course. Each group was enrolled in a different section; one section received instruction in using the scientific method; the other group did not. All other course components were the same; only Group Two had the additional instruction in using the scientific method. Both the pretest and the posttest assessments were administered in an online format.

The students logged into the Insight Assessment website to access the exam, entered their random identifier, and began the assessment. Students were given 50 minutes to complete the 33-question exam as established by the developers of the HSRT at Insight Assessments. Upon completion, the students submitted their multiple-choice answer selections, and Insight Assessments automatically recorded all results.

Insight Assessments processed the student results and generated a report for the researcher, which included the student identifier, numerical scores for the overall assessments, as well as the five subsets in analysis, deduction, evaluation induction, and inference. Insight Assessments tracks the minutes the student spent on the test and the percent of the test completed. If the student completed less than 60% of the test or spent less than 15 minutes on the test, the test results are considered invalid (Insight Assessments, 2018).

Additionally, the students that did not have a paired pretest and posttest score were eliminated from the calculations; however, all students in this study had paired pretest and

posttest scores. The results from the HSRT pretest and posttest total score were used to answer the hypothesis for the first research question for this study. The five subsets in analysis, deduction, evaluation, induction, and inference were used to answer the hypothesis for the second research question. A paired-sample t test was used to determine whether there was a statistically significant mean difference between the control group (Group One) and the experimental group (group two), recalling that at the time of the pretest, both groups completed the same didactic and laboratory courses in diagnostic medical sonography. The assumptions of one dependent variable and one independent variable were met for a paired t test. Additionally, there were no outliers identified, and the distribution of the differences in the dependent variable between the groups should be approximately normally distributed (Laerd Statistics, 2015). The two-tailed, paired t test was applied to compare the pretest data of both groups, and a statistical significance was evaluated with an alpha of 0.05. Group Two students had a higher pretest score than that of the Group One students. Group Two students ($n = 12$) ($M = 15$, $SD = 3.12$) pretest HSRT scores compared to the Group One students ($n = 12$) ($M = 14$, $SD = 3.12$), with the difference being statistically significant with an alpha of 0.05. The posttest scores reflected the same when comparing Group One and Group Two students.

Results

Insight Assessments (2018), the testing agent, generates a report of the results, based on the Health Science Reasoning Test (HSRT) results. Analyzing the results from the Insight Assessment report were used to test the hypothesis. A sample of 12 Group One students completed both the pretest and the posttest. Group Two, a sample of 12 students, also completed the pretest and the posttest. The HSRT compiles a composite score but five subsets scores for analysis, inference, evolution, inductive, and deductive reasoning. A score 25 or above indicates

the ability to solve complex problems with strong critical thinking skills, scoring 15–25 on the HSRT indicates the person has competence in critical thinking skills and can complete problem-based learning. Scores of 14 or lower suggest there are fundamental weaknesses in critical thinking skills. Scores below 10 indicate the ability to problem solve and use critical thinking is feeble and most likely will not meet most entry-level college performances. Table 2 outlines the scores.

The paired *t*-test of the Group One students did not show a significant change from the beginning of the semester to the end of the semester. There was a slight gain, but no significant gain from the pretest ($M = 14, SD = 3.12$) and posttest ($M = 18, SD = 1.78$). The paired *t* test of the Group Two students did show a significant change from the beginning of the semester to the end of the semester. There was a mean gain of 10 points, from the pretest ($M = 15, SD = 3.12$) to the posttest ($M = 25, SD = 1.78$).

To determine if there are statistically significant differences between the means of Group One and Group Two, the one-way analysis of variance (ANOVA) was used to determine the effect of instruction in the use of the scientific method improving critical thinking and reasoning skills in diagnostic medical sonography students. The one-way ANOVA was selected, as there is one independent variable in this study, testing the two groups to find if there is a significant difference between the two groups (Creswell, 2016; Laerd Statistics, 2017). The ANOVA shows there is a difference between Group One and Group Two.

The ANOVA calculator showed a significant difference in the scores of the Group One students who received no instruction in the scientific method when compared to the Group Two students who received instruction in the scientific method. The mean posttest score for the Group One students is 18, and Group Two is 26, which is an overall 8-point difference. Group One ($n =$

12, $SD = 1.71$) and Group Two ($n = 12$, $SD = 1.58$) with the f -ratio value 143.95 and the p value is < 0.00001 . The result is significant at $p < 0.05$. Group One Figure 1 shows the posttest overall scores of Group One and Group Two, while Figure 2 shows the distribution of the posttest scores for Group One and Group Two.

Group Two, following the scientific method, showed an overall improvement of their critical thinking and reasoning skills. Group Two had some scores in the red, not manifested category, which indicates insufficient test taker effort as the most likely cause since these students had previously taken the same pretest. Cognitive failure and language barriers are other factors included in the non-manifested lower scores indicating an overall score in the 0–14 range out of 33 possible. Group Two did have multiple students in the strong (green) with scores of 22–25 to superior (blue) with scores 26–33 range out of 33 possible.

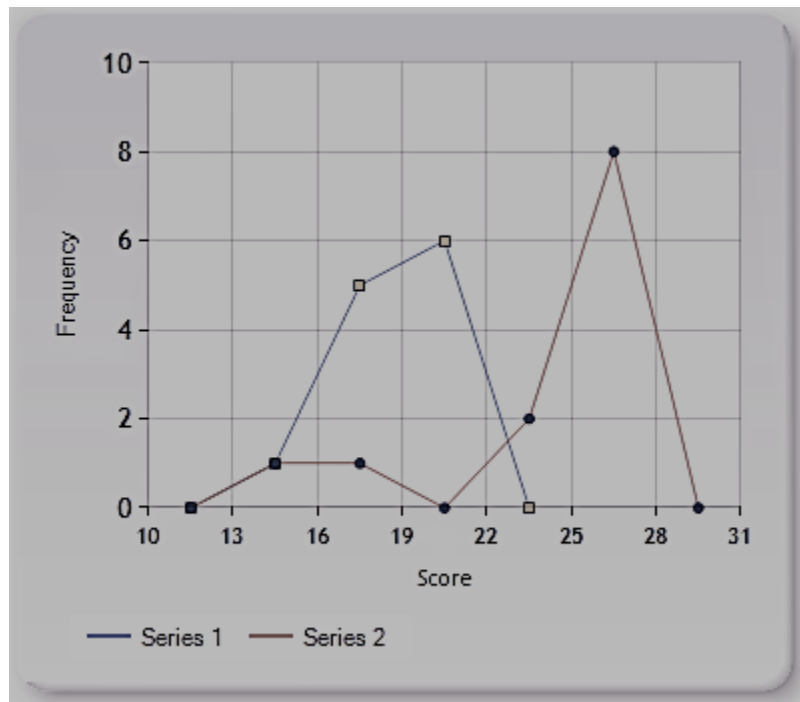


Figure 1. Overall posttest scores Group One and Group Two.

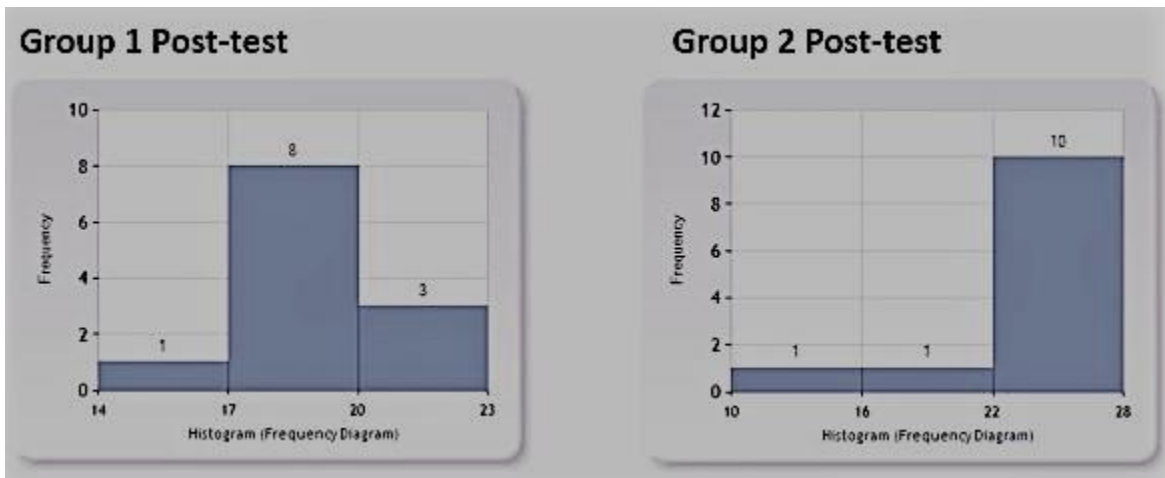


Figure 2. Distribution of posttest scores.

Statistical Analysis

Research Question 1

How significant is teaching the scientific method in improving the critical thinking and reasoning skills of diagnostic medical sonography students? To answer this question, using descriptive statistics, calculating the mean, mode, and median, variance, and standard deviation for Group One (see Table 3) and Group Two (see Table 4). Descriptive statistics are used to describe the data collected and compare the distribution of the results for Group One and Group Two (Creswell, 2016). In descriptive statistics, the central tendencies are evaluated using the mean, mode, and median. The mean is used as a central point, which provides an average of the scores for all participants in each group (Creswell, 2016). The mean can be affected by scores that are outliers on either side of the distribution of scores. The range of scores, especially the outliers, less affects the median with the results showing the middle score of all the participants (Laerd Statistics, 2015).

Table 3

Descriptive Statistic Group One

Average	Pretest	Posttest	p-value
Standard Deviation	3.12	1.77	.0072 < 0.05
Mode	17	19	
Mean	14.08	18.5	
Median	14	19	
Variance	9.72	3.15	

Table 4

Descriptive Statistic Group Two

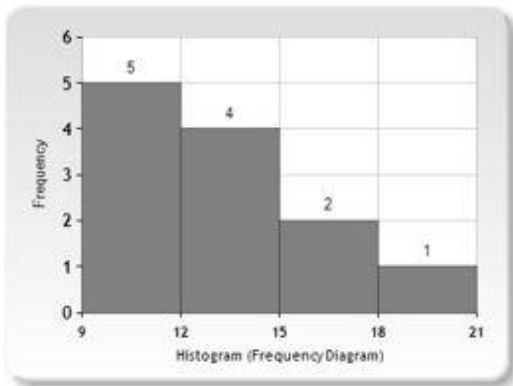
Average	Pretest	Posttest	p-value
Standard Deviation	3.2	1.77	.0005 < 0.05
Mode	18	27	
Mean	14.75	25.85	
Median	15	26	
Variance	9.72	3.15	

The one-way ANOVA calculator was used to check whether any significant differences were present between the control Group 1 and the experimental Group 2 in this study with a dependent variable (Laerd Statistics, 2017). The other assumptions concerning the one-way ANOVA were met and included the following: independence of observation, single independent variable, no significant outliers, normally distributed dependent variable for each group of the independent variable, and the homogeneity of variances (Laerd Statistics, 2017). Moreover, an ANOVA one-way was conducted to determine the difference in critical thinking in the group receiving instruction in the scientific method, which was measured by the post HSRT. The p value is < 0.00001, and the results are significant at $p = < 0.05$. Further, the one-way ANOVA demonstrated that there is a statistically significant difference between the means of Group One and Group Two, which indicates that the two groups' pre and posttest mean scores were different (Creswell, 2016; Laerd Statistics, 2017).

Group Two, after receiving instruction in the scientific method, showed an improved mean score of 11.1 points on the overall score, which is significantly greater than Group One with no instruction in the scientific method. The research question supports the alternative hypothesis and rejects the null hypothesis.

The overall scores of the HSRT measure the students' core critical reasoning ability. Comparing the small sample size of both groups to the national norms pertaining to undergraduate health science students, the average of the national percentile rankings for Group Two pretest was 16%, while that of Group Two was 29%. The average posttest rankings were 37% for Group One and 69% for Group Two. Both groups demonstrated an increase in their national percentile ranking for the posttest. Group One demonstrated an increase of 13%, and Group Two demonstrated an increase of 32%. In addition, a comparison between the pretest and posttest scores has been reflected in Figure 3 and Figure 4 for Group One and Group Two, respectively.

Group 1 Pre-test



Group 1 Post-test

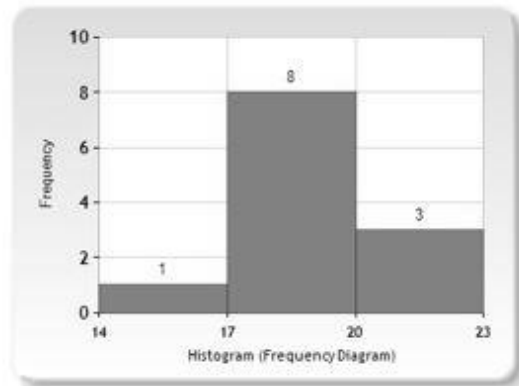
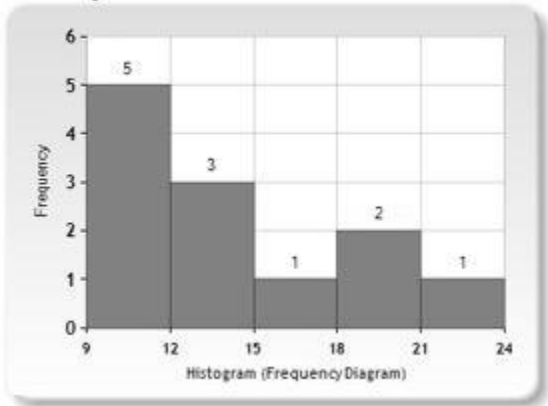


Figure 3. Overall scores Group One pre and posttests.

Group 2 Pre-test



Group 2 Post-test

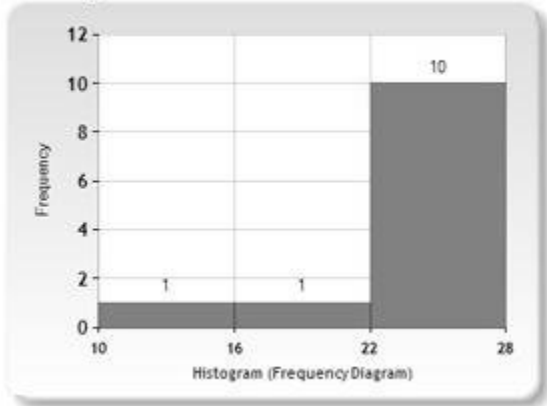


Figure 4. Overall scores Group Two pre and posttests.

The clinical supervisors were surveyed on their respective students at the end of the semester. The survey-based on the rubric in Appendix A is the evaluation instrument of the students’ critical thinking and reasoning skills correlating to the not manifested, moderate, strong, and superior scores of the testing instrument the HSRT. The benchmark is where the student achieved a moderate level, and the capstone is where the student achieved a strong or superior level. The composite and individual subsets of the clinical supervisor’s evaluations of the students are detailed below and summarized in the tables that follow.

The clinical history and observation assessment are based on the clinical supervisor's scoring of the student meeting the benchmark or the capstone. Assessed in this category was the student’s ability to gather through the clinical history of the patient’s prior imaging, laboratory tests, and surgeries. Additionally, the student’s attainment of the patient’s clinical signs and symptoms relative to the examination ordered. The distribution demonstrates more Group Two students met the capstone when compared to the Group One students that met the capstone (see Table 5). Only one Group Two students reached the benchmark where 10 Group One students achieved the benchmark.

Table 5

Comparison of Benchmark and Capstone Clinical History and Observation

Student Group	Benchmark	Capstone
Group One (<i>n</i> = 12)	10	2
Group Two (<i>n</i> = 12)	1	11

Clinical supervisors evaluated the student’s ability to correlate the clinical history to form a clinical hypothesis and expected images findings. Students who partially were able to complete the steps of the clinical hypothesis reached the benchmark, and students who completed all steps reached the capstone. Group Two had 11 of the 12 students obtaining the capstone and 1 student obtaining the benchmark (see Table 6). Group One had one student not meeting the benchmark. With two students reaching the capstone and nine reaching the benchmark (see Table 6).

Table 6

Comparison of Benchmark and Capstone Clinical Hypotheses

Student Group	Benchmark	Capstone
Group One (<i>n</i> = 12)	9	2
Group Two (<i>n</i> = 12)	1	11

Investigative imaging is where the students are scanning and evaluating the images during acquisition. The clinical supervisor evaluated the student on their ability to correlate the clinical hypotheses and history to expand the imaging protocol to prove or disprove the clinical hypothesis. The student’s ability to recognize an image answering different questions by expanding the protocol is what the clinical supervisor was evaluating. For example, the student sees a solid mass in an organ; the student should take steps to define the mass using color Doppler, Doppler, edge enhancement, tissue characterization, and other imaging parameters to gain as much information that is available through the sonographic examination. The distribution shows that Group One had two out of 12 students not meeting the benchmark, 10 students

meeting the benchmark and zero students meeting the capstone (see Table 7). The distribution for Group Two shows 10 students meeting the capstone and two students meeting the benchmark (see Table 7).

Table 7

Comparison of Benchmark and Capstone Investigative Imaging

Student Group	Below Benchmark	Benchmark	Capstone
Group One (<i>n</i> = 12)	2	10	0
Group Two (<i>n</i> = 12)	0	2	10

Sonographic findings are the correlation of the images with the clinical history. The clinical supervisor evaluated how the student correlated abnormal findings with the history and the students' ability to image all abnormal findings. The students that reach the capstone correlated all the sonographic findings with the clinical history. Students reaching the benchmark correlated some of the findings with the clinical history or did not recognize an abnormality during image acquisition. The distribution for Group One was that four students did not reach the benchmark, and eight students reached the benchmark (see Table 8). The distribution for Group Two was five students reached the benchmark, and seven students reached the capstone (see Table 8).

Table 8

Comparison of Benchmark and Capstone Sonographic Findings

Student Group	Below Benchmark	Benchmark	Capstone
Group One (<i>n</i> = 12)	4	8	0
Group Two (<i>n</i> = 12)	0	5	7

Clinical correlation is the final step in the scientific method that the clinical supervisor evaluated the student. For this category, the student will have demonstrated the ability to make all the connections between clinical history, clinical hypotheses, image acquisition, and

sonographic findings. The student that communicates these connections correctly to the clinical supervisor has reached the capstone category of proficiency, which is the capstone. Reaching the benchmark required the students to make partial connections between clinical history, clinical hypotheses, image acquisition, and sonographic findings. The distribution for Group One has four students not reaching the benchmark, seven students reaching the benchmark, and one student reaching the capstone (see Table 9). The distribution for Group Two has two students reaching the benchmark and 10 students reaching the capstone (see Table 9).

Table 9

Comparison of Benchmark and Capstone Clinical Correlation

Student Group	Below Benchmark	Benchmark	Capstone
Group One ($n = 12$)	4	7	1
Group Two ($n = 12$)	0	2	10

The clinical supervisors' evaluations support that Group Two students receiving instruction in the scientific method reached the capstone demonstrating strong and superior critically thinking and reason skills with 10 students meeting the capstone and the two students meeting the benchmark (see Table 9). The evaluations for Group One students demonstrate the students without specific instruction in the scientific method overall with one student meeting the capstone and seven students meeting the benchmark, which demonstrates moderate clinical thinking and reasoning skills (see Table 9). There were four Group One students below the benchmark, not demonstrating critical thinking and reasoning skills (see Table 9).

Research Question 2

How significant is the difference in critical thinking and reasoning skills among diagnostic medical sonography students who receive instruction using the scientific method compared to those who receive instruction using other methods?

The sign test calculator compared the posttest score of Group One and Group Two students. The Group Two students received instruction in the scientific method. The signed test shows a z value of 3.46 and a p value of .00053, with the result being significant a $p < 0.05$. Due to the size limitation of the sample in both groups where $n = 12$, the Wilcoxon signed-rank test showed the results to be significant, with the value of W is at 0. The critical value for W at $n = 12$ ($p < 0.05$) is nine. The result is significant at $p < 0.05$. The Wilcoxon signed-rank test is a nonparametric test designed to evaluate the differences between two groups that are similar. In this study, the control group and the experimental group have the same baseline characteristics (Laerd Statistics, 2017).

The results answered the research question; the improvement of critical thinking and reasoning skills were improved significantly through instruction in the scientific method. The null hypothesis was rejected, and the alternative hypothesis was accepted.

Summary

This study measured the differences in critical thinking and reasoning skills between two groups of diagnostic medical sonography students using a standardized testing instrument to measure the differences in the effectiveness of teaching the scientific method. Using the Health Science Reasoning Test (HSRT) to test the null hypothesis that there would be no significant improvement in critical thinking and reasoning skills with instruction in the use of the scientific method. Using Group One as the control group, which received no instruction in the scientific method, received the standard curriculum instruction in the diagnostic medical sonography laboratory course to compare with Group Two (experimental group). Group Two received the standard curriculum instruction in the diagnostic medical sonographic laboratory course plus instruction in the scientific method. The groups were measured in a pretest at the beginning of

the semester and posttest at the end of the semester when the instruction was completed. Individual student improvements were not evaluated in this study, but the overall class improvement the focus of this research.

The results of the paired *t*-test showed there was a significant difference between changes in the control Group One and experimental Group Two groups, $n = 12$ and $p = < 0.00001$, with the result significant at $p = < 0.05$. The use of the Wilcoxon signed-rank test showed the results to be significant with the value of W is at 0, even with the small in both groups where $n = 12$, the critical value for W at $n = 12$ ($p = < 0.05$) is nine. The result is significant at $p < 0.05$.

The results of the paired *t*-test, ANOVA and Wilcoxon signed-rank test rejected the null hypothesis that there is no significant difference in critical thinking and reasoning skills of students who receive instruction using the scientific method and those who receive instruction using the traditional/nonscientific method. These results show that instruction in the scientific method may be associated with the improvement of critical thinking and reasoning scores on the Health Science Reasoning Test from pre to posttest results. Using the clinical supervisor assessment with the rubric showing if the students were able to meet benchmark or capstone skills in critical thinking and reasoning, although subjective, concurs with the testing instrument the HSRT that the students are receiving instruction in the scientific method demonstrated improved critical thinking and reasoning skills (Insight Assessments, 2019). Additional research is necessary with a large, extensive study group that would help validate these findings.

Chapter 5: Discussion and Conclusion

Introduction

The ability to apply critical thinking and reasoning skills is essential to the diagnostic medical sonographer in clinical practice. These skills are essential as the sonographer's ability to image relevant and correlating information has a direct impact on the interpreting physician's diagnosis (Baun, 2006). Therefore, the sonographer must be able to present the imaging information accurately utilizing critical thinking and reasoning skills. The correlation of clinical history, including patient symptoms, laboratory tests, and prior diagnostic imaging, with the images, is imperative in obtaining the information necessary for the physician to interpret for the results for the patients' healthcare plan. The educational process can facilitate the development of critical thinking and reasoning skills from the classroom to the clinical experiential experience (Elder and Paul, 2013). Penny and Zachariason (2015) postulated that the educational program of the diagnostic medical sonographer must have a well-proven method to develop and gauge accurately the students' ability to transfer knowledge from the classroom to the clinical setting.

The foundation for this research project was twofold, with the first being a search for a valid instrument to gauge the improvement of diagnostic medical sonography student's critical thinking and reasoning skills. The second was to show the student improvement in correlating the bridge of classroom knowledge to the experiential clinical setting. This study evaluated the students receiving instruction is the use of the steps of the scientific method as a process to analyze and evaluate the sonographic examination in the clinical setting. As mentioned in Chapter 4, the HSRT was used as a pretest and posttest to measure the difference in critical thinking and reasoning scores. Besides, the clinical supervisors of the students in both the control and experimental group completed a subjective rubric at the end of the semester, indicating their

measurement of the students' critical thinking and reasoning skills. The benchmark indicated moderate critical thinking skills, and the capstone indicated superior critical thinking skills.

The objective of this chapter is to discuss in detail the results of the research study. The discussion will include an in-depth analysis of the results along with contrast and comparison of the most recent literature. In addition, study limitations and considerations for future research are presented. The introduction is followed by the summary of results, discussion of the results, and discussion of results relating to literature, study limitations, future research, and conclusion.

Summary of the Results

The study investigated the use of instruction in the application of the scientific method to enhance diagnostic medical sonography student's critical thinking and reasoning skills in the clinical setting. The assessment outcomes showed the students with instruction in the scientific method demonstrated a more exceptional ability to correlate their classroom knowledge to the clinical setting. Briefly, the scientific method includes observation, hypotheses, data collection, data analysis, and conclusion. The HSRT was used as an assessment of the students' critical thinking and reasoning skills to correlate how instruction in the scientific method affected the outcomes. The HSRT was used as a pretest and posttest measurement. While studies are evaluating the construct validity of the HSRT along with its response to change in comparison with another standardized testing, correlating the results to a specific teaching methodology has not been evaluated (Huhn, Black, Jensen & Deutch, 2011; Sharp, Reynolds, & Brooks, 2013).

The study design included a control group (Group One) receiving no instruction in the scientific method and the experimental group (Group Two) receiving instruction in the scientific method as described by Baun (2004), and expanded by Penny and Zachariason (2015), in

developing critical thinking and reasoning skills. Using the foundation from Baun (2004) and expanded by Penny and Zachariason (2015), the following research questions were developed:

Research Questions

1. How significant is teaching diagnostic medical sonography students the scientific method in improving their critical thinking and reasoning skills?
2. How significant is the difference in critical thinking and reasoning skills among diagnostic medical sonography students who receive instruction using the scientific method compared to those who receive instruction using other methods?

The improvement of critical thinking and reasoning skills will lead to a diagnostic medical sonographer who is equipped to analyze the images while acquiring additional relevant information for the interpreting physician as an entry-level health care professional.

Sonographers must have the ability to analyze, evaluate and correlate the information from the sonographic examination by mastering not only the technical skills to perform the exam, but the ability to form a hypothesis, interpret the images and communicate the findings to the interpreting physician (Edwards, 2006). Edwards (2006) equates the technical aspect of sonography as easier to teach than how to arrive at a differential diagnosis through interpreting the images. Critical thinking and reasoning are an essential skill set for a sonographer (Baird, 2008; Baun, 2004; Edwards, 2006; Penny & Zachariason, 2015).

In order to answer these research questions, data was obtained from a university-based bachelor degree program in the northeastern United States. The HSRT was used to evaluate the students in both the control and experimental group through pretest and posttest evaluations.

Null Hypothesis

Based on the findings presented, I rejected the null hypothesis, as supported by the data presented in Chapter 4. The rejected null hypothesis states:

H₀: There is no significant difference in the critical thinking and reasoning skills of students who receive instruction using the scientific method and those who receive instruction using the traditional/nonscientific method.

The data for this research was collected through HSRT's testing instrument, Insight Assessments. The test groups Group One and Group Two accessed and took the multiple-choice assessment test online. This study contained 33 multiple-choice questions, which measured the students' critical thinking and reasoning skills. The control group (Group One) received no instruction in the scientific method, while Group Two received instruction in the scientific method following the administration of the pretest. Each of the group participants as a pretest and a posttest took the same HSRT test at the end of the semester. The students in Group Two receiving the instruction in the scientific method showed a significant increase ($p = 0.05$) in the posttest scores following the instruction in the scientific method. The clinical instructor evaluation of the student's critical thinking and reasoning skills showed that the students in Group Two reached their capstone in each category of the steps utilizing the scientific method, thus demonstrating improved skills. Both the HSRT and the clinical instructor's evaluation during their experiential experiences showed an improvement in critical thinking and reasoning skills utilizing the scientific method.

Alternative Hypothesis

Based on the findings presents, the alternative hypothesis was accepted as supported by the data presented in Chapter 4. The accepted alternative hypothesis states:

H₁: There is a significant difference in the critical thinking and reasoning skills of students who receive instruction using the scientific method and those who receive instruction using the traditional/nonscientific method.

The data for this research was collected through a testing instrument from Insight Assessments known as the HSRT. The test groups Group One and Group Two accessed and took the multiple-choice assessment online. This study contained 33 multiple-choice questions, which measure the students' critical thinking and reasoning skills. The control Group One received no instruction in the scientific method, while Group Two received instruction in the scientific method following the administration of the pretest. Each of the group participants as a pretest and a posttest took the same HSRT test at the end of the semester. The results supported an improvement with higher scores on the HSRT in students receiving instruction in the scientific method. The students in Group Two demonstrated reaching capstone markers in their critical thinking and reasoning skills when evaluated by the clinical instructors in their experiential setting.

Discussion of the Results

The research results support past research that education in critical thinking and reasoning skills should be part of the curriculum in health science programs. The data researched found correlation with novice and expert students, demonstrating a correlation of improved critical thinking and reasoning skills developed through clinical experiential experience (Huhn et al., 2011). Another study conducted after completion of a health science program also using the HSRT as the evaluation method showed that only 315% of the students evaluated had strong critical thinking skills, in a program with no specific instruction in developing the student's critical thinking skills (Sharp et al., 2013). The results of this study show that using a defined

methodology in teaching critical thinking and reasoning skills to students demonstrated significant improvement when compared to students not receiving a defined methodology. The defined methodology in this study was the use of the scientific method applied to diagnostic medical sonography. Future research should explore other measurable methodologies to instruct students in developing critical thinking and reasoning skills.

Research question 1. Research question 1 shows an increase in HSRT posttest scores for both Group One and Group Two. Group Two received instruction in using the scientific method, showing a significant improvement over Group One, which is represented in Table 3. Group Two showed an improved score of 10.5 points on the overall score, which is significantly higher than Group One, with no instruction in the scientific method. Group One showed a slight increase of 4 points in the overall score. The ANOVA calculator supports the increase in the posttest scores of Group One and Group Two, with a 6-point difference in the mean scores. The research question supports the alternative hypothesis and rejects the null hypothesis. Students that are receiving instruction in the scientific method showed a more considerable improvement in their critical thinking and reasoning skills.

Additionally, the clinical supervisors evaluated the students on utilizing each step of the scientific method. Group Two students achieved the capstone level at a significant increase to the Group One students. Group One students showed an increase in the benchmark but rarely achieved the capstone level. The clinical supervisors evaluated their students on each of the five components of the scientific method as adapted to sonography by Penny and Zachariason (2015) as the scientific reasoning method. The first category is clinical history, which requires student observation that must be comprehensive in gathering the clinical history of the patient's prior imaging, laboratory tests, and surgeries to achieve the Capstone level. Group Two had 92% of

the students obtaining the capstone and 8 % the benchmark. Group One had one student not meeting the benchmark or capstone with 17% reaching the capstone and 75% reaching the benchmark represented by Table 5.

The second category clinical hypothesis capstone requires the student to use the clinical history correctly, forming the clinical hypotheses with correlating clinical history to the expected findings to achieve the Capstone level. The distribution shows that Group One had two students not meeting the benchmark, which is 17%, and 10 students meeting the benchmark at 83% and no students meeting the capstone. The distribution for Group Two shows that 10 students met the capstone at 83%, and two students met the benchmark at 17% represented by Table 6.

The third category of investigative imaging requires the student to consider the clinical hypotheses and history, which will guide the sonographer during image acquisition to expand the protocol to include suspected abnormalities. The distribution for Group One was that four students did not reach the benchmark at 33%, and eight students reached the benchmark at 67%. The distribution for Group Two was five students reached the benchmark at 42%, and seven students reached the capstone at 58% represented by Table 7.

The fourth category sonographic findings require that the student includes all the sonographic findings noted during the image acquisition. The student is able to focus on the abnormal findings and correlate with the clinical history. The distribution for Group One has four students not reaching the benchmark at 33%, seven students reaching the benchmark at 59%, and one student reaching the capstone at 8%. The distribution for Group Two has two students reaching the benchmark at 17% and 10 students reaching the capstone at 83% represented by Table 8.

The fifth category is a clinical correlation, where the student is able to make connections between the clinical history obtained, the clinical hypotheses, image acquisition, and sonographic findings. The Group Two students reached the capstone demonstrating strong and superior critically thinking and reason skills meeting the capstone 82% of the time and the benchmark 18% of the time. The evaluations for Group One students meant the capstone 9% of the time, and the benchmark 73%, which demonstrates moderate clinical thinking and reasoning skills. The Group One students were below the benchmark, not demonstrating critical thinking and reasoning skills 18% of the time.

Clinical case-based learning can be attributed to the elevation of Group One meeting the benchmark standards without formal didactic instruction in utilizing the scientific method. Group Two, with the instruction utilizing the scientific method in conjunction with clinically based education, were achieving Capstone, which is the considerable higher application of critical thinking and reasoning skills. All students received the same instruction in all base knowledge courses; the difference of instruction was the inclusion or absence of the scientific method. The increase HSRT posttest scores of Group One and Group Two correlates with the students receiving the benchmark or capstone rating. Group Two had a higher posttest score, which correlated to more students in Group Two, reaching the capstone level of utilizing their critical thinking and reasoning skills. Group One showed an increase although smaller from the HSRT pretest to the posttest, correlating with the majority of students in Group One meeting the benchmark indicating moderate critical thinking and reasoning skills. Both the HSRT testing and the clinical supervisor's evaluation of Group One and Group Two students validate the study's alternative hypothesis that there is a significant difference in critical thinking and reasoning skills

of students who receive instruction using the scientific method than those who receive instruction using the traditional/nonscientific method.

Research question 2. Research question 2 answers how significant is the difference in and reasoning skills among diagnostic medical sonography students who receive instruction using the scientific method compared to those who receive instruction using other methods.

The sign test calculator compared the posttest score of Group One and Group Two students. The Group Two students received instruction in the scientific method. The signed test shows a z value of 3.46 and a p value of .00053, with the result being significant a $p < 0.05$. Due to the size limitation of the sample in both groups where $n = 12$, the Wilcoxon Signed- Rank Test showed the results to be significant, with the value of W is at 0. The critical value for W at $N = 12$ ($p < 0.05$) is nine. The result is significant at $p < 0.05$. Even with the small number which is consistent with diagnostic medical sonography programs, the results show that the research question is answered, and the improvement of critical thinking and reasoning skills were improved significantly through instruction in the scientific method.

Discussion of the Results in Relation to the Literature

Research question 1. The findings in research question one is supporting the results from Foster and Lemus (2015), who explored the application of the scientific method, in astrobiology students and found that the scientific method significantly increases the post-course knowledge and critical thinking skills among students. The study indicated that there is a need for incorporation of the scientific method in other fields, especially in health education, where the ability to think and reason critically is of utmost importance. In order to improve critical thinking and reasoning skills in diagnostic medical sonography students, the application of the scientific was tested in this study agreeing with the Foster and Lemus (2015) study. Improved

critical thinking and reasoning skills facilitate the sonographer in extracting pertinent information was the examination allowing relevant images for review by the interpreting physician, ultimately providing better patient care. Latif et al. (2016) investigated concept mapping as an education and learning tool in the development of critical thinking skills among nursing students that encourage them to connect new information to their prior knowledge. The findings indicated that concept mapping could improve critical thinking skills among nursing students and allow students to transfer and apply academic knowledge to clinical practice. By utilizing the five-step scientific method incorporated in their sonography instruction, there was a bridging of the student's academic knowledge to the clinical setting. Although no formal concept mapping was utilized and studied as a variable in this study, concept mapping incidentally was applied in the development of instruction.

This study was on a much smaller scale and specific to applying instruction in the scientific method to diagnostic medical sonography students to bridge their classroom and clinical knowledge. The researcher's experiences have helped formulate the conceptual framework for this study and by the constructivism theory, including reflexivity (McGarrity, 2013; Singh & Rajput, 2013; Zmuda et al., 2015). According to McGarrity (2013) and Zmuda et al. (2015), the constructivist approach instills critical thinking skills by the students becoming active participants in their learning and not just memorizing facts.

Reale, Riche, Witt, Baker, and Peeters, (2018), conducted a meta-analysis of established testing instruments evaluating critical thinking skills in health professions. Standardized tests included were the California Critical Thinking Skills Test (CCTST), the Defining Issues Test (DIT), and, the HSRT. The conclusions drawn from the analysis were the CCTST, and DIT showed change over time in the cognitive ability of students from different allied health

professions comprised of nursing, pharmacy, dental hygiene, dentistry, occupational therapy, physical therapy, medicine, veterinary medicine, and clinical laboratory sciences (Reale et al., 2018). After screening, 79 studies were evaluated, which represented over 6000 students by Reale et al. (2018). The results included the standardized mean differences (SMD) and confidence intervals (CI) along with Cohen's kappa (0.82), which was strong for inter-reviewer agreement. Cohen's kappa is a coefficient that measures the agreement in qualitative studies between the different reviewers. The HSRT had mixed results, and a smaller number of students were assessed using this standardized test. However, the results show the HSRT was not responsive to change among the students (Reale et al., 2018). Reale's (2018) et al., study evaluated many programs with no specific instructional methodology evaluated; the study demonstrates that standardized testing is a valid instrument. Although my study demonstrated a change scores from the pretest to the posttest, it was on a much smaller scale with specific instruction to the experimental group of students. Specific instruction in applying the scientific method systematically for each patient examination shows that instructors have a methodology that will improve their student's critical thinking and reasoning skills.

Prior research supports the use of instructional methods to improve critical thinking skills by Goodman, Redmond, Harris, Augustine, & Hand, 2018) using the HSRT-N, which is a validated assessment from Insight Assessments to assess the critical thinking skills of registered dietitian nutritionists (RDN). Goodman et al. (2018) utilized a think-aloud case study, which involved the participant receiving a case study 24 hours before the interview. The participant was asked to describe everything they would do based on the information presented in the case study. In retrospect, this think-aloud case study is the same as the classroom activity used in a group project in the classroom, with the scientific method applied to diagnostic medical sonography.

The students applied the scientific methodology to actual clinical cases in the classroom before their clinical experiential experience. This researcher had the students continue to use the scientific method for their clinical cases in the experiential setting. At the student's clinical site visit, two cases were presented to the researcher. Goodman et al. (2018), further validate the importance of developing and fine-tuning critical thinking and reasoning skills in all health professions. This study correlates the classroom instruction and the clinical experiential experiences fine-tuning the students' clinical thinking and reasoning skills by using the scientific methodology.

Students need instruction through learning activities to bridge the didactic or knowledge-based instruction into the clinical setting by analyzing and applying their knowledge as applied to the patient's examination, as modeling behavior of the clinical instructor does not provide complete development of the critical thinking and reasoning skills (McInerney & Baird, 2016). Critical thinking is the process, using the scientific method that the sonographer uses to make a judgment about the patient history and information obtained from the sonographic images, which facilitate the diagnosis and treatment of the patient (Penny & Zachariason, 2015). In 2004, Baun was the first to propose in the literature using the scientific method for integrating patient history and sonographic findings from the examination through critical thinking, and reasoning is a crucial part of the cognitive functions of the sonographer (Baun, 2004). The use was subjective as it was dependent on the individual sonographer's ability, but no formal validity testing in teaching the scientific method as proposed by Baun (2004), or the variation of the scientific reasoning method proposed by Penny and Zachariason (2015). Both of these methods provided tools to cultivate the sharing of clinical cases and enhance critical thinking and learning skills (Penny & Zachariason, 2015).

The HSRT test in this study was able to show a difference between the control group (Group One) and the experimental group (Group Two) with Group Two, demonstrating a higher posttest score after receiving instruction in the scientific method. The validity of the HSRT as a measure indicates that there is statistical data to support the scientific method as part of the instruction in developing critical thinking and reasoning skills, thus rejecting the null hypothesis.

Research question 2. Research question 2 asks how significant is the difference in critical thinking and reasoning skills among diagnostic medical sonography students who receive instruction using the scientific method compared to those who receive instruction using other methods?

There are limited studies that have evaluated the validity and significance of HSRT. Other studies left questions of what educators can do to instruct students to improve their critical thinking and reasoning skills. Huhn, Black, Jensen, and Deutch (2011) conducted a study on physical therapy students to evaluate the construct validity of HSRT with results discriminating, demonstrating critical thinking skills of expert ($n = 73$) and novice ($n = 79$) physical therapists. The total overall critical thinking scores were compared with an independent t -test, and the subsets were evaluated using ANOVA (Huhn, Black, Jensen & Deutch, 2011). Additional studies by Cox and McLaughlin (2014), Kelsch, and Friesner (2014) established that the test was reliable in measuring the critical thinking skills and clinical performance of healthcare. The first-year doctor of pharmacy students were evaluated in the Cox and McLaughlin study with a significantly higher number of participants ($N = 329$) to establish the validity of the HSRT with the student's experiential performance. Friesner (2014) studied the HSRT for their impact on the admissions process to the Doctor of Pharmacy program with ($N = 122$) determined that the HSRT could be an effective method to evaluate critical thinking as part of the admission process.

Another study conducted on graduates in allied health and health informatics by Sharp, Reynolds, & Brooks (2013) showed that ($N = 57$) the participants did not have strong critical thinking and reasoning skills measured by the HSRT upon graduation. Sharp et al. (2013) study showed the need for further education in developing critical thinking and reasoning skills. In this study, the HSRT was able to evaluate pre and posttest groups of the control and experimental group and allow comparisons between the groups.

Limitations

Because this study utilized data from an eastern United States university granting a bachelor degree in diagnostic medical sonography, the results may not apply to other diagnostic medical sonography programs. The Commission on Allied Health Education Programs (CAAHEP) lists programmatic accredited programs showing 222 associate degree programs and 87 bachelor degree programs in the United States. The control and experimental group collection of data were completed, knowing the small sample size presents limitations (Faber, 2014). Diagnostic medical sonography programs typically have a small enrollment in each cohort. The external validity of this study will need to be measured with other diagnostic medical sonography programs. External validity allows the generalizations to be accessed from a single study (Laerd Statistics, 2012).

Furthermore, external validity asks the questions of how the information from this study can be generalized to other diagnostic medical sonography programs. Secondly, will instructional methodology in the scientific method transfer to improvement in critical thinking and reasoning skills in other diagnostic medical sonography programs? The study's internal validity is based on the accuracy of how instruction in the scientific method will improve the student's critical thinking and reasoning skills, providing confidence that this methodology

explains the results between Group One and Group Two (Laerd Statistics, 2012). A threat to the internal validity for both groups one and two in this study is the experiential experience, an extraneous variable, as each student's experience is similar but different (Laerd Statistics, 2012). In designing research, the extraneous variable can be minimized, in the fact that all students are in similar experiential experiences, but the individual difference is present, but the experiential setting is defined as creating an equivalent setting (Laerd Statics, 2012). Critical thinking and reasoning involve many parameters, and the outcomes from this study will need other programs to replicate and may include additional variables to the study. Additional variables such as the program size, degree level, types of clinical experiential facilities, and student demographics. The current study focused on the overall HSRT score and the subjective evaluation from the clinical instructors.

Implication of the Results for Practice, Policy, and Theory

Practice. This study was implemented to determine if there was a valid construct instrument to measure the improvement of critical thinking and reasoning skills with the application of a formal methodology. Combining the HSRT testing with the clinical instructor's assessment of students indicates there is validity for using the scientific method as advocated by Baun (2004) and Penny and Zachariason (2015). In theory, many components formulate critical thinking and reasoning skills. Educators should formulate their methodology to strengthen their student's critical thinking and reasoning skills, but where should their efforts be focused.

My personal experience with using the scientific method as a process in correlating didactic, laboratory, and clinical experiential experience the student's critical thinking and reasoning skills have improved. Each step of the scientific method is presented, discussed, and then worked through with a case in the classroom prior to the students using the process with

each clinical exam in the experiential setting. The students work through each step of the scientific process with each examination, having selected cases with written documentation to present to their classmates and faculty. The student's skill set in evaluating, analyzing, and correlating the information has shown improvement, which was documented in the clinical supervisor's assessment as well as my personal experience with students. The results are that a student is able to present more detailed information through the images to the referring physician, thus improving patient care.

Policy. Examined in this study was the student's score on the HSRT after receiving instruction using the scientific method in their clinical experiential experience to bridge their classroom and laboratory course work to the clinical setting. The findings were that the HSRT posttest scores and the Benchmark/Capstone evaluation showed that instruction in the scientific method led to improved scores in the student's critical thinking and reasoning. For future curricular revision, building the inclusion of the teaching methodology of the scientific method into the classroom and experiential experience courses will support the bridging of academic knowledge with the clinical skillset. The clinical experiential experience schedule should have time for the faculty to meet with the students and discuss cases utilizing the scientific method and strengthening the student's critical thinking and reasoning skills.

Theory. This research project's conceptual framework was based on the theory that a defined methodology in teaching critical thinking and reasoning skills will improve the student's ability. Constructivism includes the cognitive, which takes acquired information and connects it to knowledge, thus involving critical thinking and reasoning (McInerney & Baird, 2016). Furthermore, constructivism involves developing social interactions as part of this knowledge base (Singh & Rajput, 2013). Another aspect of constructivist theory is reflexivity, where the

student becomes an active participant in their learning process, gathering information, analyzing data, and making connections to draw a conclusion (McGarrity, 2013; Singh & Rajput, 2013; Zmuda et al., 2015). The constructivist theory can facilitate educators in developing an instructional methodology for teaching critical thinking and reasoning skills.

The challenge is for educators to develop an instructional methodology that demonstrates higher education and professional requirements of critical thinking and reasoning skills (Baird, 2008). Credential boards and professional organizations' expectations are that diagnostic medical sonographers can have the knowledge, skillset, and clinical knowledge, which bridges the classroom and practice in the clinical setting (Baird, 2008, McInerney & Baird, 2016). Planned activities foster the development of critical thinking and reasoning skills (McInerney & Baird, 2016). Implementation of a measurable methodology to improve the student's skillset requires support from the administrative level to support the educator in the classroom and clinical experiential experience. The clinical supervisors' evaluations supported that providing instruction in the scientific method improved the sonography student's ability to demonstrate capstone level critical thinking and reasoning skills.

Recommendations for Further Research

The results obtained were from a small sample volume based at one university; further studies should evaluate if instruction in the scientific method demonstrates an improvement in critical thinking and reasoning skills in the program at their college. Program curriculum varies, which can influence the results of any study. Further studies should include a larger sample volume, and evaluation of the five subsets included in the overall score of the HSRT from Insight Assessments. The five subsets that are included in the overall score on the HSRT are analysis, inference, evaluation, induction, and deduction. A larger sample volume may come

from two or more programs involved in the research study. Adding other components to the methodology will provide more options for assessing student skills and outcomes.

Conclusion

Developing critical thinking and reasoning skills are essential for sonographers as their ability has a direct impact on the interpreting physician's diagnosis (Baun, 2006). Students need instruction to develop critical thinking and reasoning skills, which primarily have been taught by modeling the sonographers in the clinical experience. Educators need to foster learning activities that cultivate and foster clinical thinking and reasoning skills in the student. McInerney and Baird (2016) advocated that activities improve the critical thinking and reasoning skills in students. This study demonstrated the use of the scientific method as an instructional method in the classroom and laboratory with application in the clinical setting. Thus, making the connection and bridging the gap between the classroom, laboratory, and clinical experiential education.

The quantitative quasi-experimental study to add validity to including instruction in the scientific method to enhance the critical thinking and reasoning skills of diagnostic medical sonography students. The HSRT overall scores demonstrated a significant improvement of scores from the students receiving instruction in the scientific method, successfully bridging their didactic and laboratory knowledge to the clinical setting. Educators do need guidelines to provide an introduction of teaching methodologies into their curriculum. Further exploration of different methodologies to improve the critical thinking and reasoning skills will only benefit the students and, ultimately, the patients receiving a sonographic examination.

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Appendix A: Clinical Instructors Evaluation

Criteria	Benchmark	Capstone
Clinical History and Observation	The student gathered a partial history of the patient. Additional history was reflected in the final report and brought out in the discussion	The student gathered through the clinical history of the patient's prior imaging, laboratory tests, and surgeries. The student obtained the patient's clinical signs, and symptoms relative to the examination ordered
Clinical Hypotheses	Limited clinical history but still attempting to correlate the clinical history to the expected findings to form the clinical hypotheses of the findings will be limited	Correct use of the clinical history, the clinical hypotheses will be formed correlating clinical history to the expected findings
Investigative Imaging	The clinical hypotheses and history will guide the sonographer during image acquisition to expand the protocol to include suspected abnormalities.	The clinical hypotheses and history will guide the sonographer during image acquisition to expand the protocol to include suspected abnormalities.
Sonographic Findings	The student does not include all the sonographic findings noted during the image acquisition. The student is not able to accurately identify all abnormal findings and/or correlate with the clinical history.	The student includes all the sonographic findings noted during the image acquisition. The student is able to focus on the abnormal findings and correlate with the clinical history.
Clinical Correlation	The student is able to make partial connections between the clinical history obtained, the clinical hypotheses, image acquisition, and sonographic findings.	The student is able to make connections between the clinical history obtained, the clinical hypotheses, image acquisition, and sonographic findings.

Appendix B: Statement of Original Work

The Concordia University Doctorate of Education Program is a collaborative community of scholar-practitioners, who seek to transform society by pursuing ethically-informed, rigorously-researched, inquiry-based projects that benefit professional, institutional, and local educational contexts. Each member of the community affirms throughout their program of study, adherence to the principles and standards outlined in the Concordia University Academic Integrity Policy. This policy states the following:

Statement of academic integrity.

As a member of the Concordia University community, I will neither engage in fraudulent or unauthorized behaviors in the presentation and completion of my work, nor will I provide unauthorized assistance to others.

Explanations:

What does “fraudulent” mean?

“Fraudulent” work is any material submitted for evaluation that is falsely or improperly presented as one’s own. This includes, but is not limited to texts, graphics and other multi-media files appropriated from any source, including another individual, that are intentionally presented as all or part of a candidate’s final work without full and complete documentation.

What is “unauthorized” assistance?

“Unauthorized assistance” refers to any support candidates solicit in the completion of their work, that has not been either explicitly specified as appropriate by the instructor, or any assistance that is understood in the class context as inappropriate. This can include, but is not limited to:

- Use of unauthorized notes or another’s work during an online test
- Use of unauthorized notes or personal assistance in an online exam setting
- Inappropriate collaboration in preparation and/or completion of a project
- Unauthorized solicitation of professional resources for the completion of the work.

Statement of Original Work (Continued)

I attest that:

1. I have read, understood, and complied with all aspects of the Concordia University–Portland Academic Integrity Policy during the development and writing of this dissertation.
2. Where information and/or materials from outside sources has been used in the production of this dissertation, all information and/or materials from outside sources has been properly referenced, and all permissions required for use of the information and/or materials have been obtained, in accordance with research standards outlined in the *Publication Manual of The American Psychological Association*.

Debra Crandell

Digital Signature

Debra Crandell

Name (Typed)

October 12, 2019

Date