EXAMINING THE IMPACT OF PROFESSIONAL DEVELOPMENT ON SCIENCE TEACHERS' KNOWLEDGE AND SELF-EFFICACY: A CAUSAL-COMPARATIVE INQUIRY

A Dissertation

by

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This dissertation meets the standards for scope and quality of
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ABSTRACT

The United States of America and other countries have focused on reforming education to help increase students' science literacy. Teachers directly impact student learning; therefore, they are the key to this change. Teacher professional development is instrumental in influencing student learning. Few research studies have been conducted with an intensive, explicit professional development model, focusing on in-service science teachers.

The primary purpose of the study was to test the hypotheses that teachers who receive intensive, explicit professional development have higher teacher self-efficacy and earth-science content knowledge than do teachers who do not receive the intervention. The causal-comparative study took place in the Victoria Crossroad and Coastal Bend region of South Texas. There were 60 participants in the characteristic-present group and 42 in the comparison group. External validity was limited to study participants due to the non-probability nature of the sampling. Because of the non-experimental nature of the study, no causal inferences were drawn. The results of the study did not support the hypotheses. Self-efficacy was further divided into two subscales: Personal Science Teaching Efficacy beliefs (PSTE) and Science Teaching Outcome Expectancies (STOE). For all subjects, the PSTE score was higher than were the STOE scores; the difference was statistically significant, and the mean difference effect size was large.

The success of professional development programs depends on identification and understanding teacher's knowledge and perceptions, before the creation of the program. Therefore, schools, districts, third-party providers, and states need to focus on their teachers' needs and consider them in designing and implementing professional development programs. To raise teacher's self-efficacy, professional development facilitators need to allocate time for

teachers to practice inquiry and other scientific skills. Professional development facilitators also need to be skilled in mentoring adults.

DEDICATION

This dissertation is dedicated to my family, who is my everything. To my sons, Timothy and Jacob and my husband, Rob, thank you for your endless love and support throughout this journey. You gave me the courage to pursue this dream. I love the three of you very much!

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CHAPTER I

INTRODUCTION

Background and Setting

The United States of America (USA) lags behind other countries regarding student science achievement, which is distressing, considering their goal of being the most scientifically advanced country in the world (Beaton et al., 1996; Xie, Fang, & Shauman, 2015). To counter this, the USA has focused on educational reform to increase the science literacy of all students. Many other countries have also clamored for a change in science education (Xiufeng, 2009). As a result, participation in the international science assessments has increased to measure where the USA stands in this competitive global workforce. The high school international assessment, Program for International Student Assessment (PISA), from the Organization for Economic Co-operation and Development (OECD, 2014), has grown from 43 countries in 2000 to 71 countries in 2015. The middle school international science assessment, Trends in International Mathematics and Science Study (TIMSS), had shown a growth of 29 nations in 1995 to 40 in 2015. Sun, Bradley, and Akers (2012) asserted that governments and educational officials scrutinize their students' rank in the assessments to track their ranking against other global competitors as well as to dissect any differences. The USA ranked 11th in the 2015 TIMSS 8th grade science assessment behind Singapore, Japan, Taiwan, Korea, Slovenia, Hong Kong, Russia, England, Kazakhstan, and Ireland. (National Center for Education Statistics, 2017). The average scores on the eighth-grade science test have increased from 1995, 1999, and 2007-2015 but regrettably, there was no measurable difference between the USA's 8th-grade science scores between 2011 to 2015 (National Center for Education Statistics, 2017). The student's results have increased from 513 points in 1995 to 530 in 2015 (National Center for Education Statistics, 2017).

Numerous studies have demonstrated that teachers are critical to reform education (Bantwini, 2010). Not only do teachers have to teach the science content but also, they need to teach science literacy explicitly. Science literacy involves scientific knowledge as well as understanding the history of science (HOS) and nature of science (NOS). Lederman (2007) and Seker (2012) asserted that understanding HOS and NOS are vital and critical to science literacy. Seker (2012) contended that teaching the HOS may improve the knowledge of the NOS. Abd-El-Khalick, Lederman, Bell, and Schwartz (2002) define NOS as “the epistemology and sociology of science, science as a way of knowing, or the values, and beliefs inherent to scientific knowledge and its development” (p. 498). The NOS positions science as a way to understand and explain the natural world. Science educators have agreed that the six aspects of the NOS should be taught to K-12 students; specifically, (1) scientific knowledge is tentative (subject to change); (2) is based on creativity (the invention of concepts and explanations); (3) is empirically-based (derived from observations of the natural world); (4) includes observations and inferences; (5) is theory-laden and subjective; and (6) consists of laws that describe patterns in the natural world (Donnelly & Argyle, 2011). These aspects of the NOS are an essential part of epistemology in which scientific knowledge is produced “through critical, negotiated, and collaborative inquiries that are propelled by scientists’ imagination and only bound by their observation of the natural world” (Ssempala, 2015, p. 463). Milner, Sondergeld, and Rop (2014) agreed with Abd-El-Khalick. Lederman, Bell, and Schwartz (2002)’s definition of NOS and six aspects and purposed that the definition and the aspects combined to provide “a complete and practical working definition of NOS” (p. 2). To develop students’ science literacy, teachers need to address the scientific knowledge, the HOS, and the NOS (Maeng & Bell, 2013).

Increasing students' understanding of the NOS has been a goal of science education since the 1950s (Lederman, 1986; Lederman, 2007; Lederman & Lederman, 2014; Rubba, Horner, & Smith, 1981). In the 1980s, researchers found science was taught as unchanging facts out of a textbook and discovered science curriculum did not reflect the changing views of science (Duschle, 1988; Khishfe, Alshaya, BouJaoude, Mansour, & Alrudiyan, 2017). Teachers rarely took pre-service courses that examined the epistemological and ontological stance of the NOS; therefore, their efforts lacked the skills and knowledge necessary to explicitly teach the NOS in their classrooms (Abd-El-Khalick et al., 2017; Matthews, 1994). In 1990, science education reform emphasized the need for students to have an understanding of the NOS (American Association for the Advancement of Science (AAAS), 1993; National Research Council, 1996). Project 2061 began in 1985 (AAAS, 1995), and with the release of the Next Generation Science Standards (NGSS) framework (NGSS Lead States, 2013), science curricula began to focus on the NOS. Lederman (2007) and Abd-El-Khalick et al. (2017) indicated that many teachers and students still had an inadequate understanding of the NOS.

There are still many misconceptions with both students and teachers regarding the NOS. For example, Maeng and Bell (2013) reported some teachers and students believed that hypotheses were educated guesses, which became theories, and then over time became laws. Also, there is a misconception that laws are valued more than theories (Wong & Jeffery, 2015). Some teachers and students thought that there was a single step-wise method, the scientific method, to systematically conduct science research. In some science classrooms, students accepted that their data proved that their hypothesis was either right or wrong and overlooked the value of evidence in supporting or refuting conclusions (Maeng & Bell, 2013). Lederman

(2007) asserted that regardless of the number of years of teaching experience, disciplines taught, or teaching assignment (elementary, middle school, or high school), teachers do not have an adequate understanding of the NOS.

The literature has shown that in science methods courses, pre-service teachers received the most HOS and NOS instruction (Abd-El-Khalick & Akerson, 2009; Abd-El-Khalick, Bell, & Lederman, 1998; Akerson, Abd-El-Khalick, & Lederman, 2000; Seung, Bryan, & Butler, 2009; Tsai, 2006). Only a relative few studies have found the HOS and the NOS instruction in pure science content courses (Abd-El-Khalick, 2001; Donnelly & Argyle, 2011; McDonald, 2010). Early studies focused on teachers' NOS understanding as the main factor affecting the teaching of the NOS to their students; however, it was also shown that a teachers' understanding did not translate into classroom teaching (Abd-El-Khalick & Lederman, 2000; Clough, 2006; Lederman, 2007). Lederman and Lederman (2014) and Abd-El-Khalick and Lederman (2000) asserted that there were many reasons why teachers' understanding of the NOS did not improve student understandings.

Science teachers often depended on teacher-directed instruction or utilized reform curriculum materials differently than how the curriculum developers intended (Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, 2009). The NOS has not been an instructional objective in the classroom historically (Lederman & Lederman, 2014). Many teachers reported that they did not feel confident in their views of the NOS (Abd-El-Khalick & Lederman, 2000; Lederman, 1999 Lederman & Lederman, 2014); thus, decreasing the likelihood of them incorporating the NOS into classroom instruction. The HOS instruction improved the understanding of the NOS; however, that influence was limited (Seker, 2012). Wang and March (2002) and Hottecke and Silva (2011) indicated teachers did not attach importance to be inclusion of the historical elements.

To teach the NOS effectively, teachers must “understand and notice [NOS] issues entangled in science content and its development, and then effectively incorporate [those] with the content instruction” (Clough, 2006, pp. 487–488). Research has shown that teachers’ NOS pedagogical content knowledge influences the classroom teaching of the NOS (Clough, 2006; Lederman, 2007; Sondergeld, Milner, & Rop, 2014). Teachers need to know when, how, and why to teach a specific aspect of the NOS. When teachers understand how science works, then they can model appropriate behaviors, attitudes, and practices that scientists use. They can also teach the topics conceptually which helps students learn the concepts.

Fishman, Marx, Best, and Tal (2003) and Luft and Hewson (2014) asserted that professional development should foster changes in knowledge, beliefs, and attitudes of teachers. Ultimately, that change could lead teachers to acquire new skills, pedagogical practices, and expertise (Fishman, Marx, Best, & Tal, 2003; Luft & Hewson, 2014). Deehan (2017) asserted that professional development practices, such as NOS instruction, could produce positive growth in teachers’ science teaching efficacy beliefs. A change in teachers’ knowledge, beliefs, attitudes, and self-efficacy have shown a strong correlation to teachers’ classroom practices (Fishman, Marx, Best, & Tal, 2003; Haney, Lumpe & Czerniak, 2002; Luft & Hewson, 2014). Teachers with high teaching self-efficacy were more likely to have open attitudes about trying new instructional strategies (Bahcivan and Kapucu, 2014; Ghaith & Yaghi, 1997).

The mission of the Texas Regional Collaboratives (TRC) is to provide Texas mathematics and science teachers “with support systems of scientifically researched, sustained, and high intensity professional development and mentoring to assist them in the implementation of the Texas Essential Knowledge and Skills (TEKS)” (Texas Regional Collaboratives, n.d.). For twenty-four years, the TRC, which is a state-side network of 57 P-16 partnerships, has provided research-based, Professional Development Programs (PDPs) that has included instructional models and materials to embed the new knowledge into their classrooms (Texas Regional Collaboratives, 2015). During the 2015-2016 school year, the TRC served 7,792 teachers on 2, 195 campuses representing 778 school districts (TRC, 2018). The TRC's ultimate goal is to equip teachers with current knowledge and best practices to improve Texas students' scientific thinking and literacy. The Texas Education Agency (TEA) recommended the content of the yearly PDPs (Texas Regional Collaboratives, 2017). Teachers choose to apply to be a member of the local TRC. During the 2015-2016 school year, the TRC's professional development classes focused on earth and space science (TRC, 2018).

Statement of the Problem

Few research studies have been conducted with an intensive, explicit professional development model, focusing on in-service science teachers. Two studies, Cofre et al., 2014, and Sondergeld, Milner, and Rop, 2014, employed similar designs like the one used in this study and found that teacher's NOS understanding did improve after a year-long science content professional development; however, neither study compared the treatment group to other teachers who did not receive the professional development in their region. Also, neither study examined if the intensive, explicit science professional development increased teacher self-efficacy or teacher content knowledge.

Theoretical Framework

Teachers directly affect student learning; therefore, teacher quality is paramount. Teacher professional development is a significant variable in influencing student learning (Borko, 2004; Desimone, Smith, & Phillips, 2007). Many studies have demonstrated the lack of success of the professional development. Teachers criticized learning in professional training as not applicable to their day-to-day teaching (Darling-Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009; Putnam & Borko, 2000). One-shot, one-day professional development training is inadequate to produce change (Borko, 2004; Darling-Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009). According to The New Teacher Initiative study (2015), most schools are not providing the professional development that teachers need.

Loucks-Horsley, Love, Stiles, Mundry, and Hewson (2003) and Bahcivan and Kapucu (2014) stressed that teachers' beliefs impact their learning and in turn, their teaching. Additionally, what a person believes in his or her confidence to learn and complete academic tasks signifies a person's self-efficacy. Professional development training developed with the goal of affecting teachers' belief systems and practice will in turn influence student learning.

One of the current study's theoretical frameworks was Bandura's theory of self-efficacy, which assumes teachers' self-efficacy is related to their expectations and efforts to implement change in the classroom. Bandura (1994) defined perceived self-efficacy as "people's beliefs about their capabilities to produce designative levels of performance that exercise influence over the events that affect their lives." (p. 1). Teacher self-efficacy is the confidence a teacher has in attempting to perform a specific task successfully (Deehan, 2017). Fisherman, Marx, Best, and Tal (2003) asserted that teacher beliefs had demonstrated a correlation to instructional practice; therefore, an objective of professional development should be to influence those views positively. Bhattacharyya, Volk, and Lumpe (2009) went further and stated that professional development had to focus not only on the content knowledge and pedagogy but also on increasing teachers' self-efficacy in an attempt to affect classroom instructional practices. Lakshmanan, Heath, Perlmutter, and Elder (2011) argued that if professional development focused on increasing teacher self-efficacy, it would eventually result in improving student achievement. Bruce, Esmonde, Ross, Dookie, and Beatty (2010) demonstrated that there was a relationship between teacher self-efficacy and increased student achievement.

The second theoretical framework driving this study was Kolb's Experiential Learning Theory; a process in which knowledge is created through experience (Kolb, 1984). A four-stage cycle makes up the theory. A learner has a concrete experience which leads to reviewing or reflecting on the experience. The learner's reflection provides an opportunity for analysis and conclusion. Finally, the learner applies the new idea/modification to the world around themselves to test it out which results in new experiences setting a new cycle in motion. Kolb (1984) believed that learning is an integrated process in which each stage feeds into the next one; he asserted that effective learning is achieved when a person can go through all four stages.

Purpose of the Study

The primary purpose of the study was to test the hypotheses that teachers who receive intensive, explicit professional development have higher teacher self-efficacy and earth and space science content knowledge than do teachers who do not receive the intervention. The following research questions guided the study:

1. How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on self-efficacy?
2. How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on earth and space science content knowledge?

Operational Definitions

For the purpose of the study, self-efficacy was measured by the respondents' responses to

The Science Teaching Efficacy Belief Instrument - A, STEBI - A (Riggs & Enochs, 1990). The STEBI - A is a valid and reliable measure of teachers' science teaching efficacy (Deehan, 2017). A multiple-choice test on earth and space science measured the teachers' content knowledge.

The characteristic-present group consisted of secondary science teachers from the Victoria Crossroads and the Coastal Bend parts of south Texas that had volunteered to participate in one hundred hours of professional development in earth and space science. The comparison group consisted of secondary science teachers from the Victoria Crossroads and the Coastal Bend parts of south Texas who volunteered to take a survey. For the purpose of the study, the secondary science teachers were teaching 6^{th} through 12^{th} grades.

Glossary of Terms and Acronyms Used Throughout the Paper

- Beliefs refer to idiosyncratic unity of thoughts about objects, people, and events (Mansour, 2013).
- ESSKT – Earth and Space Science Knowledge Test
- Experiential learning is the process whereby knowledge is created through the transformation of experience (Kolb, 1984).
- HOS – History of science
- NOS – Nature of science
- Nature of Science is the epistemology and sociology of science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2002; Milner, Sondergeld, & Rop, 2014)
- PSTE – Personal Science Teaching Efficacy beliefs

- Personal Science Teaching Efficacy subscales measure a teacher's belief in his or her own capacity to effectively teach predetermined science skills and knowledge to their students (Deehan, 2017).
- Professional development is an ongoing learning experience for teachers that continues throughout the teaching career (Luft & Hewson, 2014) and develops an individual's skills, knowledge, expertise, and other characteristics as a teacher (Organisation for Economic Co-operation and Development, 2008).
- SBOE – State Board of Education (in Texas)
- Science refers to a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge based on evidence from many investigations that is integrated into highly developed and well-tested theories that can explain bodies of data and predict outcomes of further investigations (National Research Council, 2012).
- Science literacy is the knowledge of science, the investigative nature of science; science as a way of thinking, and the interaction of science, technology, and society (Saad & BouJaoude, 2012).
- Self-Efficacy is defined as the perceived beliefs, judgments or capabilities of a person about performing actions at designated levels (Bandura, 1977).
- STAAR – State of Texas Assessments of Academic Readiness
- STEBI – Science Teaching Efficacy Belief Instrument
- STOE – Science Teaching Outcome Expectancies
- Science Teaching Outcome Expectancies subscale measures a teacher's beliefs about the capacity of science teaching to overcome external factors such as student's family

- background, socioeconomic status (SES) or school conditions to aid students' science learning (Deehan, 2017).
- TEA - Texas Education Agency
- Teacher self-efficacy refers to the teacher's perceived ability to impart knowledge and to affect student behavior (Tschannen-Moran & McMaster, 2009).
- TEKS – Texas Essential Knowledge and Skills
- TKSEQ – Teacher Knowledge and Self-Efficacy Questionnaire
- TRC – Texas Regional Collaboratives

Delimitations, Limitations, and Assumptions

The study was delimited to (1) secondary science teachers in Victoria Crossroads and the Coastal Bend regions of south Texas, (2) the independent variable of professional development, and (3) the outcome measures of the knowledge of earth and space science and self-efficacy. The study used non-probability samples; therefore, the external validity was limited to the study's participants. Due to the non-experimental nature of the study, no causal inferences were drawn. It was assumed that the study's participants were honest in completing the instruments used to measure the outcome variables.

Significance of the Study

Science education reformers have determined that teaching the NOS is vital to the advancement of increased science literacy in teachers and students alike. Researchers assert that NOS is essential to science literacy but rarely taught because of naïve NOS views held by classroom teachers; therefore, teacher's professional development is a key to increasing students' understanding of the NOS (Donnelly and Argyle, 2011; Milner, Sodergeld, & Rop, 2014). To influence teachers' understanding of the NOS and the related pedagogical content knowledge, they need intensive, sustained professional development that is explicitly taught with opportunity for reflection.

In the state of Texas, students in the eighth grade take a state-mandated, standardized science test, cumulatively covering the content that they learn in the sixth, seventh, and eighth grade (Texas Educational Agency, 2017). The earth and space science content is an area of weakness for eighth-grade students statewide but especially in the study's area (Lead4ward, 2017). In order to increase student's earth and space science knowledge, TRC developed an earth and space science curriculum for a yearlong, intensive, explicit teacher professional development (TRC, n.d.). Teachers self-select to participate in this professional development class. This research study was developed and conducted to test the hypotheses that the characteristic-present group's self-efficacy and earth and space science content knowledge would be higher than a comparison group's measures of the variables of interest. Although the obtained data did not support the hypotheses, the results offered practical and theoretical implications. When $18,000 per year per teacher is spent on professional development, then school districts and educational entities must provide professional learning that promotes a change to the teacher's practice and skills (The New Teacher Initiative, 2015).

Chapter II

REVIEW OF THE LITERATURE

Chapter 2 provides a thorough review of the literature and research related to adult education, professional development, and science professional development. In retrieving the literature, the following search engines and literature databases were utilized: Mary and Jeff Bell Library at Texas A&M University-Corpus Christi, Google Scholar, SAGE, Eric-Education Resources Information Center, ProQuest, EBSCO, and Wiley Online Library.

Learning and Intelligence

Humans from the time that they are born until their last breath are always learning (Merriam & Bierema, 2014). Theories about human intelligence have been prolific throughout the ages. Plato wrote about human knowledge in his piece *The Myth of the Cave*. Aristotle believed that “all men by nature desire to know” (Magee, 1998, 2001, p. 36). Descartes focused on the question “What can I know?” (p. 84). Teachers of ancient times had classes full of adults, not children (Ozuah, 2005).

In the seventh century, the focus on teaching was switched from adults to children when monasteries established schools for children (Merriam & Bierema, 2014). The theory of teaching children or pedagogy was developed and spread throughout (Knowles, 1973). Pedagogy comes from Greek, and it means leader of children. Most teachers would mention developmental psychologist, Jean Piaget’s theory of cognitive development when asked about theories that have impacted their knowledge about intelligence (Campbell & Campbell, 1999). Haggbloom et al. (2002) asserted that Piaget placed second after Freud in terms of journal citations and second after B. F. Skinner as the most quoted psychologist in the 20th century. Howard Gardner, in *Wrestling with Jean Piaget, my Paragon*, called Piaget a “giant in the field”

(2008, p. 1).

In the 1920s, Jean Piaget was employed to develop French intelligence tests at the Binet Institute (McLeod, 2015). The reasoning that children gave for their wrong answers fascinated him (McLeod, 2015). That intrigue prompted Jean Piaget to study cognitive development. He published more than 50 books and 500 papers as well as 37 volumes in the series *Studies in Genetic Epistemology*. He described himself as a genetic epistemologist, not a cognitive psychologist (Hopkins, 2011; Piaget, 1936). The term genetic was a synonym for the term developmental (Hopkins, 2011). Piaget believed that intelligence was a single ability that developed the same way in individuals. "Intelligence is an adaptation…To say that intelligence is a particular instance of biological adaptation is thus to suppose that it is essentially an organization and that its function is to structure the universe just as the organism structures its immediate environment" (Piaget, 1963, pp. 3-4).

Piaget demonstrated that children think differently than adults. In *Conversations with Jean Piaget*, he said "Education, for most people, means trying to lead the child to resemble the typical adult of his society ... but for me and no one else, education means making creators... You have to make inventors, innovators—not conformists" (Bringuier, 1980, p. 132). Piaget was interested in the problem of education, but he believed that the role of the psychologist was to develop facts that educators could utilize (Bringuier, 1980). Piaget stated "It's the pedagogue's job to see how he can use what we offer. Pedagogy is not simply applied psychology; it's a whole set of techniques the specialist has to fit together by himself" (Bringuier, 1980, p. 60).

Despite the significant impact Piaget's theories had, many researchers have criticized a number of Piaget's methods. McLeod (2015) asserted that Piaget's data were based on his own subjective interpretation of events because he conducted the observations alone. Piaget's methodology was comprised of a lack of controls, small sample size, and absence of statistical analysis. Very rarely did he report how he selected his participants or statistics other than the ages of the individual children and number of children in the study (Hopkins, 2011). In *The Origins of Intelligence in Children,* his participants were his own three children. He asserted that his methods were acceptable as long as he was able to identify structures common to all individuals (Edwards, Hopgood, Rosenberg, & Rush, 2000).

Piaget believed that children's' development must precede their learning (1952). Piaget also discounted the role of society in children's development. He overlooked the effects of students' cultural and social groups (Edwards, Hopgood, Rosenberg, & Rush, 2000). Vygotsky argued, "learning is a necessary and universal aspect of the process of developing culturally organized, specifically human psychological function" (1978, p. 90). In other words, social learning tends to precede development.

Early in his career, Howard Gardner, a developmental psychologist, believed he would follow in Piagetian tradition. Piaget asked "How does the mind develop?" which Gardner regarded as the most important question in cognitive psychology. However, when Gardner reflected over his career, he realized that "the bulk of my scholarly career has been a critique of the principal claims that Piaget put forth" (Gardner, 2008, p.1). Piaget believed that intelligence was a single ability that developed the same way in individuals. Howard Gardner's view of intelligence was different. After working with two different groups, brain-damaged adults, and normal and gifted children, Gardner developed a theory that synthesized his observations and research (Gardner, 1983). First, in his book *Frames of Mind: Theory of Multiple Intelligences*, Howard Gardner (1983) asserted a person's intelligence is not a single construct but seven relatively autonomous, but interdependent, intelligences. Secondly, he believed that intelligences were related to a person's unique aptitude or set of capabilities and how a person might prefer to demonstrate intellectual abilities. Gardner (1983) stressed the importance of considering each individual as a "collection of aptitudes" (p. 27) rather than through a single Intelligence Quotient (IQ) test.

According to Gardner, the theory of multiple intelligences (MI) was a model of intelligence that differentiated intelligence into specific modalities, and these intelligences helped individuals use human capital effectively in complex environments. Gardner (1993) believed there were seven intelligences: 1) verbal-linguistic intelligence (verbal skills), 2) logical-mathematical intelligence (ability to think conceptually and abstractly), 3) spatial-visual intelligence (capacity to think in images and pictures), 4) bodily-kinesthetic intelligence (ability to control one's body movements), 5) musical intelligence (ability to produce and appreciate rhythm), 6) interpersonal intelligence (capacity to detect ad respond appropriately to moods, motivations, and desire of others), and 7) intrapersonal (capacity to be self-aware). He believed the first two were valued in schools; the next three were associated with the arts; and the final two were personal intelligences (Gardner, 1999, pp. 41-43).

In his book, *Multiple Intelligence*, Gardner asserted that people who use a particular intelligence do so with all their other intelligences (1993). Gardner also believed that people tend to learn subject matters that are related to their level and type of intelligence. Based on his theory, people who are logically intelligent are better prepared to learn science and mathematics.

In the 1983 book, *Frames of Minds: The Theory of Multiple Intelligences,* Gardner's assumption about what made up intelligence has caused people to confuse intelligence with a domain or a discipline. After studying creativity with Mihaly Csikszentmihalyi and David Feldman, Gardner redefined intelligence as a biological and psychological potential; that potential is capable of being realized to a greater or lesser extent as a consequence of the experiential, cultural, and motivational factors that affect a person" (Gardner, 1995).

Unlike Piaget, Gardner believed that there is both a biological and cultural basis for the multiple intelligences. According to Saadatmanesh (2014), the cultural context in which the intelligence operates is one of the most important aspects of the theory of MI. There are cultures that focus on some types of intelligences, whereas, other cultures accentuate other intelligences.

Another difference between Piaget's and Gardner's theory of intelligence was Gardner's could be extended to adult education. Shearer (1998) developed a tool for measuring MI in adults; however, one criticism of MI is the lack of empirical support and testing tools. Daniel Willingham, University of Virginia professor of psychology, believed that Gardner's theory falls apart when closely examined. He asserted that the criteria for intelligences were "too loose" and allowed for the possible inclusion of intelligences such as humor or memory (Willingham, 2004). Morgan (1992) asserted several of the intelligences could not be conceptually distinguished from one another.

Andragogy

In the 1950s, European educators began using the term "andragogy" when referring to adult education (Knowles, 1973). Andragogy comes from two Greeks words when translated means the art and science of helping adult students learn (Knowles, 1973). Boston University Professor Malcolm Knowles popularized the term in the first edition of The Modern Practice of Adult Education: Andragogy versus Pedagogy (1970). He proposed six assumptions about the adult learner 1) As someone matures, his/her self-concept changes from being dependent personality to self-directed; 2) An adult has a wealth of experience which acts as a resource for learning; 3) An adult's readiness to learn is related to the task or his/her social role; 4) Due to the fact that a person's time perspective matures, adult's learning tends to be more problem-centered than subject-centered; 5) Adults are intrinsically motivated; 6) In order to learn, adults need to know the reason (Knowles, 1980 & 1984).

Adult learning is never separate from the adult learner's life and the world (Merriam & Biererma, 2014). It is intimately entwined in it. Merriam & Bierema (2014) divided adult learning settings into formal, nonformal, and informal settings. A formal learning setting is an educational institute, such as a university (Merriam & Bierema, 2014). Sandman (2010) asserted that thirty-six percent of students enrolled in college were twenty-five years and older. Merriam and Bierema (2014) defined nonformal learning is typically done in places where education is its secondary purpose such as workplace training, teacher professional development, genealogy classes at the local library, and/or learning to grout at Home Depot. Nonformal learning is voluntary and typically short-term (Merriam & Bierema, 2014). Informal learning is everyday learning (Coombs, 1985; Illeris, 2004, Merriam & Bierema, 2014). It is the learning that adults do to program their new smartphone, to cook a new dish, and/or to install new software.

Teacher professional development can increase knowledge and skills, which can be instrumental in improving teaching practices (Desimone, 2011). The enhancement of abilities can lead teachers to grow in three ways, namely, personal, social, and emotional (Desimone, 2011). Professional learning can occur in a variety of formal and non-formal settings; for example, college courses, in-service days, workshops hosted by educational entities outside the school district, and hallway discussion among colleagues, which can provide the opportunity for teacher growth and development (Borko, 2004; Cochran-Smith & Lytle, 1999; Desimone, 2011).

Science Education

Since Sputnik crossed the skies over middle America in 1957, there have been many reports, journal articles, and white papers calling for the need to reform science education (Munck, 2007). In 1996, the National Research Council (NRC) released the National Science Education Standards (NSES). The standards (NSES) laid out the science content necessary for students (NRC, 1996). NSES focused on inquiry as for the best strategy in order for students to learn science content and NOS; however, teachers ultimately decide what and how things are taught in their classroom (AAAS, 1995). Science teachers often depend on traditional teacher-directed instruction or utilize reformed curriculum materials differently than how the curriculum developers intended (Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, 2009).

In the 1980s, researchers found science was taught as unchanging facts out of a textbook and discovered science curriculum did not reflect the changing views of science (Duschl, 1988). Milner, Sondergeld, & Rop (2014) and Von Glassersfeld (2001) asserted that learners were passive when the teachers employed traditional teaching methods such as lecture and the learners struggle to construct an understanding of science concepts, relationships, and/or content. A growing body of research has demonstrated that poor teaching is linked to poor standardized test scores (Munck, 2007; DiBiase & McDonald, 2015). DiBiase and McDonald (2015) asserted that classroom issues such as class size, accountability, curricular demands, and administrative support were reasons teachers cited to impede the use of inquiry to teach science.

Teachers rarely took pre-service courses that examined the epistemological and ontological stance of the NOS; therefore, their efforts lacked the skills and knowledge necessary to explicitly teach the NOS in their classrooms (Matthews, 1994). In 1990, science education reform emphasized the need for students to have an understanding of the NOS and inquiry

(American Association for the Advancement of Science (AAAS), 1993; National Research Council, 1996). Munck (2007) asserted that science education reform must focus on quality teaching as well as curriculum content.

Jones and Carter (2007) stated that "teacher beliefs are key to understanding and reforming science education." Teacher's beliefs are fundamental to who they are and their educational research principles will dictate their practice (DiBiase & McDonald, 2015).

Middle School Science Education in Texas

In Texas, science is taught from kindergarten to 12th grade. The state science standards, Texas Essential Knowledge and Skills (TEKS), were created by the state of Texas to clarify what students from kindergarten through 12th grade should know and be able to do. Texas State Legislature gave the State Board of Education (SBOE) the authority to adopt the TEKS for each content area, including science (TEA, 2017). The Science TEKS for science were updated in 2010 (TEA, 2017; Charles A. Dana Center, 2014).

The TEKS are divided into three sub-chapters: (1) elementary, (2) middle school, and (3) high school, and each is further divided into (1) introduction and (2) knowledge and skills. The knowledge and skills segment consists of (1) scientific investigation and reasoning, (2) matter and energy, (3) force, motion and energy, (4) earth and space, and (5) organisms and environment (Charles A. Dana Center, 2014). Scientific processes are included in the scientific investigation and reasoning (TEA, 2017).

The State of Texas Assessments of Academic Readiness (STAAR) is the state-mandated standardized test. The 5th and 8th grade students take a comprehensive science examination that tests the knowledge and skills segment of the TEKS. There are four categories: (1) matter and energy, (2) force, motion and energy, (3) earth and space, and (4) organisms and environment, on the test. The fifth part of the TEKS, scientific investigation and reasoning, is embedded in the above-mentioned four categories (Lead4Ward, 2017; Texas Education Agency, 2017).

Earth and Space Science Standards in Texas

Earth and space is the third reporting category on the 8th grade science standards test Different earth and space science topics are taught in 6th, 7th, and 8th grades. The 8th grade students take a state-standardized science test over 6th, 7th, and 8th grade content in May (TEA, 2017).

The earth and space standards in 6th grade focus on the structure of the earth, the rock cycle, and plate tectonics. The 6th grade science students must (1) build a model to illustrate the compositional and mechanical layers of Earth, including the inner core, outer core, mantle, crust, asthenosphere, and lithosphere; (2) classify rocks as metamorphic, igneous, or sedimentary by the processes of their formation; (3) identify the major tectonic plates, including Eurasian, African, Indo- Australian, Pacific, North American, and South American; and (4) describe how plate tectonics causes major geological events such as ocean basin formation, earthquakes, volcanic eruptions, and mountain building (TEA, 2017, pp. 43-44).

Another earth and space topic that 6th grade students must be taught is the solar system and its organization. Students are expected to (1) describe the physical properties, locations, and movements of the sun, planets, moons, meteors, asteroids, and comets; (2) understand that gravity is the force that governs the motion of our solar system; and (3) describe the history and future of space exploration, including the types of equipment and transportation needed for space travel (TEA, 2017, p. 44).

At the 7th grade, students have fewer earth and space science standards than do 6th and 8th grade students. The focus of the majority of the science topics a seventh-grade, and the focus in on life science (TEA, 2017). The 7th grade students are expected to (1) analyze the characteristics of objects in our solar system that allow life to exist such as the proximity of the Sun, presence of water, and composition of the atmosphere; and (2) identify the accommodations, considering the characteristics of our solar system, that enabled manned space exploration (TEKS, 2017, p. 52). In earth science, the 7th graders learn to (1) predict and describe how catastrophic events such as floods, hurricanes, or tornadoes impact ecosystems; (2) analyze the effects of weathering, erosion, and deposition on the environment in ecoregions of Texas; and (3) model the effects of human activity on groundwater and surface water in a watershed (TEA, 2017, p. 51).

At the 8th grade, students have more earth and space science standards to learn than do 6th and 7th graders. The first set of science standards are about the relationship between the sun, earth, and moon. Eighth-grade science students are expected to (1) model and illustrate how the tilted earth rotates on its axis, causing day and night, and revolves around the sun, causing changes in seasons; (2) demonstrate and predict the sequence of events in the lunar cycle; and (3) relate the position of the moon and sun to their effect on ocean tides (TEA, 2017, pp. 59-60).

Building on the 6th and 7th grade science standards, which focus on the solar system, 8th grade students learn about the universe and its components. Students are expected to (A) describe components of the universe, including stars, nebulae, and galaxies, and use models such as the Herztsprung-Russell diagram for classification; (2) recognize that the sun is a medium-sized star located in a spiral arm of the Milky Way galaxy and that the sun is many thousands of times closer to earth than any other star; (3) identfy how different wavelengths of the electromagnetic spectrum such as light and radio waves are used to gain information about components in the universe; and (4) research how scientific data are used as evidence to develop scientific theories to describe the origin of the universe (TEA, 2017, p. 60).

At the 8th grade, students learn about earth as a system as well. They learn about how natural events alter Earth. Students are expected to (1) describe the historical development of evidence that supports plate tectonic theory; (2) relate plate tectonics to the formation of crustal features; and (3) interpret topographic maps and satellite views to identify land and erosional features and predict how these features may be reshaped by weathering (TEA, 2017, p. 60). Students learn about the relationships in different earth systems such as the ocean and weather connection, and are expected to (1) recognize that the sun provides the energy that drives convection within the atmosphere and oceans, producing winds; (2) identify how global patterns of atmospheric movement influence local weather using weather maps that show high and low pressures and fronts; and (3) identify the role of the oceans in the formation of weather systems such as hurricanes. (TEA, 2017, p. 61).

Texas Science teachers must be able to teach the above-mentioned standards to Texas middle school students. Students will take a state-mandated test over all the 6th, 7th, and 8th grade standards at the end of 8th grade (Lead4Ward, 2017). Goodwin and Hubbell (2013) reported that students do better on state mandated tests if they are taught what is tested and asserted that aligning curriculum to state-mandated assessments has the strongest link to student success, noting that teachers are recommended to provide instruction over what is important for students to learn. Chenoweth (2007, 2009) found that student performance improved when schools had clearly defined curriculum that outlined what students learn in every grade level and in every class; it is using the standards as guideposts.

Professional Development

Merriam and Bierema (2014) asserted that a professional could not learn everything they will need to know for the course of the career. Information doubles every two years and online information doubles every 90 days (Merriam & Bierema, 2014). Most professional preparation becomes outdated before one gets situated in a career (Merrriam & Bierema, 2014). Teachers directly impact student learning; therefore, teacher quality is paramount. Teacher professional development is a significant variable in affecting student learning (Borko, 2004; Desimone, Smith & Phillips, 2007).

Many studies have demonstrated the lack of success of the professional development. Putnam and Boroko (2000) reported that teachers' criticism of learning in professional training was not applicable to their day-to-day teaching. One-shot, one-day professional development training is inadequate to produce change (Borko, 2004; Darling-Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009). Michael McNeff, a superintendent, pointed out that "the easiest and least effective way to address professional development is to provide one-size-fits-all professional learning opportunities, which mean only a portion of attendees finds it valuable" (McNeff, 2017, p. 12). Most school district officials include professional development days as part of their yearly calendar. Then they struggle to develop professional development programs that individualize the learning to make it meaningful for all teachers, knowing that the aim of professional learning is to change educator's practice for the better (McNeff, 2017). Knight (2011) stated that the goal of professional development is to provide learning opportunities to "explore, prod, stretch, and re-create whatever it is they are studying- to roll up their sleeves, really consider how they teach, really learn a new approach, and then reconsider their teacher practices and reshape the new approach, if necessary, until it can work in their classroom (p. 43).

Blank, de las Alas, and Smith (2008) examined 25 teacher professional development programs. The critical elements of an effective professional development program included the duration of over 50 hours, continuous coaching, aligned to the curriculum, and ongoing teacher collaboration. Darling-Hammond, Wei, Andree, Richardson, & Orphanos (2009) expanded that list to include multiple opportunities for classroom application. The model of professional development had four key facets: content, active learning, the coherence of learning to teachers' professional needs, and duration (Desimone, 2009). Desimone (2009) purposed that when the professional development encompassed these four attributes, then the teachers' knowledge, skills, beliefs, and attitudes would improve which in turn would impact students' achievement.

McNeff (2017) asserted that professional development needs to occur throughout the school day as well as the year, noted that traditional professional development occurs during the summer, at night and on the weekends; and believed that professional development that occurs outside of school day leads to disconnected learning because it is not connected to the classroom and rarely impacts learning. The National Staff Development Council advocates professional learning occurring "several times per week among established teams of teachers, principals, and other instructional staff members where the teams of educators engage in a continuous cycle of improvement" (National Staff Development Council, 2009, p. 2).

Science Professional Development

Teacher professional development was a significant variable in affecting student learning (Desimone, Smith & Phillips, 2007); therefore, quality NOS professional development is paramount. According to Donnelly and Argyle (2011), NOS instructional strategies such as explicit reflective pedagogy improved teachers' NOS views. Education researchers, Milner, Sondergeld and Rop (2014) asserted that teachers could learn NOS through explicit professional development opportunities. Professional development training courses that included real-world experiences such as working with scientists were also successful in improving teachers' views (Akerson, Cullen, & Hanson, 2009). Donnelly and Argyle (2011) discovered that teachers were willing to adopt new strategies and instructional activities after a year-long monthly professional development in which NOS was connected to science content.

Past studies have demonstrated that explicit and reflective teaching has been effective. (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000; Bell, Matkins, & Gansneder, 2011; Schwartz, Lederman, & Crawford, 2004) Different frameworks have examined including Schwartz, Lederman and Crawford's (2004) study of 21 in-service secondary science teachers in a full immersion scientific research program. The results indicated teachers' NOS increased; however, there was little time for reflection. The growth in NOS understanding ranged from 10 percent to 48 percent. Other studies found that intensive yearlong professional development programs had an impact on teachers' NOS understanding, NOS pedagogical content knowledge, and classroom instructional practices. Akerson and Hanusein (2007) asserted that teachers NOS understanding changed from inadequate to developing via the Views of the Nature of Science (VNOS-B) questionnaire after an intensive summer workshop and monthly follow-up workshops for the next year where NOS was explicitly taught (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2002). The VNOS-B questions allow teachers to examine their beliefs in order to answer the 10 open-ended questions on different parts of NOS such as science is empirical, tentative, inferential, creative, theory-laden, and social.

Donnelly and Argyle (2011) stressed that after a year-long monthly professional development, teachers were willing to adopt new strategies and instructional activities changing their NOS pedagogical content knowledge. Zhang, McInerney, and Frechtling (2010) concluded that professional development where scientists and teachers formed a learning partnership helped to grow the teachers' NOS views.

Cofre et al. (2014) researched the change in teachers' NOS understanding in a year-long science content professional development with two NOS mini-courses. These researchers were the "first study to use NOS courses [explicitly taught] in combination with subject matter courses to improve the NOS understanding of middle school in-service teachers" (p. 760). The study's results showed that the middle school in-service teachers' informed NOS view ranged from 33 to 42 percent. Cofre et al. (2014) stated that the participants' reflective journals were not examined, just the survey results. The research focus of the study was to investigate teacher beliefs; therefore, studying the reflective journals was paramount to understand how professional development influences changes in teacher beliefs and attitudes.

A search of the literature uncovered only one other study that focused on understanding middle school science teachers' NOS understanding using a similar design as the study mentioned above. The study had one NOS mini-course that lasted two weeks in the summer and included ongoing professional development classes during the fall semester (Sondergeld, Milner, & Rop, 2014). Surveys administered at specific intervals with the final one given three months after the final class to determine long-term effects on the learning of the participants. The results showed that the study's design impacted the teachers' NOS understandings.

Science education reformers have determined that teaching HOS is vital to the advancement of increased science literacy in teachers and students alike. Teachers are the key to students accurately developing NOS understanding. To order to influence teachers' HOS and NOS understanding and their pedagogical content knowledge, teachers need intensive, sustained professional development that is explicitly taught with opportunity for reflection.

Theoretical Framework

In teaching science, the teacher's beliefs and attitudes have been the focus of educational research (DiBiase & McDonald, 2015; Mintzes, Marcum, Messerschmidt-Yates, 2013)). Harwood, Hansen, and Lotter (2006) and Bahcivan & Kapucu (2014) asserted that teacher beliefs are key to understand teacher's practice. Teachers' beliefs impact their teaching and professional development learning (Bahcivan & Kapucu, 2014; Harwood, Hansen & Lotter, 2006; Pajares, 1992). Pajares (1992) argued that teacher beliefs are inherited from their own years as a K-12 student as well as their teacher preparation program. Bahcivan and Kapucu (2014) asserted that science teachers teach science as they learned it. DiBiase and McDonald (2015) stated that educational beliefs impact how teachers interpret pedagogical knowledge.

Bandura's Social Learning Theory defines self-efficacy as an individual's confidence to successfully engage in complicated and/or difficult tasks (Bandura, 1977, 1982; Meece et al., 1990). He theorized that people are motivated to perform an action if they believe the work will have a positive result (outcome expectation), and they are confident that they can accomplish that task successfully (self-efficacy expectation). A person with a high level of self-efficacy will overcome complex tasks by endeavoring in efforts to achieve them. On the flip side, people with lower levels of self-efficacy will avoid complex tasks.

Bandura (1982) asserted that four factors, enactive attainments or mastery experiences, vicarious experience, verbal persuasion, and physiological state, affect self-efficacy. Bahcivan and Kapucu (2014) stated that enactive attainments have the most influential effect on self-efficacy. Enactive attainments are based on mastery experiences that could result in success or failure. A person's success would increase his/her self-efficacy; whereas, failure would decrease self-efficacy. People's self-efficacy can increase or drop by watching others. Vicarious experiences are when a person observes a model. When a person sees his/her model having success, then the person's self-efficacy increases (Bahcivan & Kapucu, 2014; Bandura, 1982). The reverse is also true. Verbal persuasion or social persuasion is an encouragement to others to make a person believe in his/her abilities to achieve the desired outcome (Bahcivan & Kapucu, 2014; Bandura, 1982). The fourth factor is a person's physiological state. People's reaction to their performance can enhance their self-efficacy if they deem their performance as first-rate, and the reverse is also true; that is, if a person functions poorly, then his/her her self-efficacy decreases (Bahcivan & Kapucu, 2014).

Teacher self-efficacy is the perceived ability to impart knowledge and to affect student behavior (Tschannen-Moran & McMaster, 2009). A teacher's self-efficacy is related to the amount of effort s/he invests, the professional goals, the perseverance, especially when things do not go smoothly, and the resilience in the face of setback (Tschannen-Moran & McMaster, 2009) Haney, Wang, Keil, and Zoffel (2007) asserted that a teacher's self-efficacy is related to classroom behavior and implementation of instructional change. Teachers with high efficacy are more likely to try new instructional strategies in order to improve their teaching practices and tend to work more with students with classroom difficulties (Palmer, Dixon & Archer, 2015).

Consistent with Bandura's theory, teacher self-efficacy has two dimensions: personal teaching efficacy and outcome expectancy (Bahcivan & Kapucu, 2014). The first aspect has two parts, namely, teaching efficacy and personal efficacy; the first refers to a teacher's belief about the link between teaching and learning and the second involves a teacher's opinion about his/her own effectiveness (Bahcivan & Kapucu, 2014). An individual's expectations related to achieving a task according to a desirable outcome is outcome expectancy, which is in line with Bandura's theory (Bahcivan & Kapucu, 2014). Many studies have asserted that teachers with a high self-efficacy work harder, persist longer, and have a stronger motivation to help students learn (Bahcivan & Kapucu, 2014; Bleicher & Lindgren, 2005; Ramey-Gassert et al., 1996).

Focusing on teaching science, a teacher's self-efficacy may be revealed in his/her own confidence in teaching middle school science. Self-efficacy is contextually dependent. A teacher could have a high self-efficacy in teaching some science content such as the energy pyramid but have a low level of self-efficacy in other areas such as energy transformations. *Science Teaching Efficacy Belief Instrument* (STEBI) developed by Riggs and Enochs (1990) was validated in order to assess science teachers' self-efficacy. The instrument is comprised of two dimensions: Personal Science Teaching Efficacy and Science Teaching Outcome Expectancy. Research has demonstrated that individuals with a strong science background such as the number of college science courses, science teaching method courses, and preference for inquiry-based teaching have higher levels of self-efficacy (Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013).

Professional development training needs to be developed in order to impact teachers' belief systems and practice which in turn will influence student learning. Mintzes, Marcum, Messerschmidt-Yates, and Mark (2013) found that professional development that provided opportunities to collaborate with other science teachers had a positive effect on science teachers' self-efficacy.

For the last few decades, science education studies have been conducted to determine cognitive and affective abilities. The constructivist theory has dominated these studies (Cavas, 2011). According to Cavas, people are not passive in learning. They do not just absorb the information. Instead, meaningful learning involves the active creation and modification of knowledge structures. When people learn new things, they use their prior knowledge, beliefs, and interests to make the new topic understandable to themselves. Their interpretation of the new experience may result in a change in their prior knowledge, beliefs, and interests.

Girvan, Connelly, and Tangney (2016) affirmed that many research studies had used experiential learning theory as a theoretical framework. Kolb asserted knowledge was a result of the interaction between theory and experience and defined experiential learning as the process of creating knowledge through the transformation of experience (Kolb, 1984). Learning from experience is not memorizing facts to regurgitate them on a test. Dunlap, Dobrovolny and Young (2008) proclaimed learning was a process in which transformation experiences created new knowledge.

The experiential learning theory is comprised of four stages: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation (Kolb, 1984; Tomkins & Ulus, 2015). The cycle begins when a learner has a learning experience and an opportunity to reflect on the experience and his/her prior knowledge. The experience could be new or a reinterpretation of existing experience. Then the learner can conceptualize and draw conclusions about his/her experiences. The learner focuses on any inconsistencies between the experience and understanding. This reflection could lead to future ideas, actions, or modifications in which learners can experiment with different behavior. The learner applies the new ideas, actions, or modifications to the world around him/her to investigate the result of this new information, which leads to the beginning of the cycle again. “Learning is a process whereby knowledge is created through the transformation of experience” (Kolb, 1984, p. 38).

Kolb proposed that for an effective learning experience, a learner must go through all four stages to fully investigate the topic through various activities and different learning styles. He asserted that learning was integrated and that each stage supported and fed into the next one.

Summary

Understanding the nature of science (NOS) is vital and critical component of science literacy (Lederman, 2007, Seker, 2012). Increasing the science literacy of its citizens is a goal of the United States (Xie, Fang, & Shauman, 2015). Teachers' beliefs, their pedagogical and NOS knowledge, and how they incorporate it into the classroom influence student understanding of science and NOS. People are unique; therefore, what professional development training and activities that trigger a change in their pedagogical beliefs and classroom practices are based on their personalities and circumstances. Conducting a study would gather participants' beliefs, opinions, knowledge, and feelings to build a complete picture of the phenomenon. Crotty (1998) believed that "truth or meanings, comes into existence in and out of our engagement with the realities in our world" (p. 8). Meanings are constructed by humans as they are involved with their surroundings. Each of the teachers has distinct beliefs and knowledge.

Chapter III

METHOD

Chapter Three describes the procedures that were implemented to meet the objectives of the study. The following research questions guided the study:

1. How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on self-efficacy?
2. How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on earth and space science content knowledge?

Research Design

The study employed an ex-post facto, causal-comparative design, which required forming groups of individuals in whom independent variable is present or absent (Gall, Gall, & Borg, 2007, 2015). The ex-post facto (or after the fact) design attempts to use the independent variable(s) to explain the outcome measure(s), that is, focusing on events that have already occurred. A comparison group is selected from a population that is similar to the characteristic-present group except for the variable(s)/characteristic(s) that is/are being investigated. For the purpose of this study, the teachers who had received the 100 hours of science content professional development formed the characteristic-present group, and the comparison group consisted of teachers who had not received the intervention, which was the independent variable. The outcome measures were the teachers' self-efficacy and earth and space science content knowledge. Due to non-experimental nature of the study, no causal inferences were drawn.

Subject Selection

The study took place in the Victoria Crossroads and the Coastal Bend regions of south Texas, which include urban, suburban, and rural areas alongside the Gulf of Mexico. Although there is a mixture of cultures, it is a primarily Hispanic area. The major cities in the region are Victoria, Corpus Christi, and Kingsville. The subjects for the study's characteristic-present group were teachers in the Texas Regional Collaborative (TRC) that provided members with over 100 hours of science professional development per year. There were two different TRC groups in the study's region. The same person was in charge of both teacher groups. The professional development sessions focused on inquiry-based science instruction, science content knowledge (focusing on earth and space science), the NOS, and the state science standards. The comparison group included teachers that either did not apply for or were not selected for the year-long professional development and only received the district-provided professional development. Permission to conduct the study was obtained from the Institutional Review Board (IRB) at Texas A&M University-Corpus Christi (HSRP# 83-17).

All members of the two TRCs were invited to participate (n = 75) via email, of which, 60 voluntarily agreed to participate in the study. Using a snowball sampling technique, the members of the TRCs helped recruit teachers for the comparison group, as well as using the Educational Service Center secondary science teacher email list, local school districts secondary science teacher email list, and regional informal science education teacher email lists. All potential comparison group teachers received an email and were invited to participate in the study; 42 provided useable data by completing the online survey instrument.

Instrumentation

For the purpose of the study, a 3-part survey instrument, Teacher Knowledge and Self-Efficacy Questionnaire (TKSEQ) was developed by the researcher (Appendix A). Parts I and II included the Science Teaching Efficacy Belief Instrument – A, STEBI A, (Riggs & Enochs,

1990) and the Earth and Space Science Knowledge Test (ESSKT), respectively. Part III was used to collect data on selected demographic characteristics of the participants.

The STEBI - A is a valid and reliable measure of teachers' science teaching efficacy (Deehan, 2017), which consists of two sections, namely, Personal Science Teaching Efficacy beliefs (PSTE) and Science Teaching Outcome Expectancies (STOE). The PTSE measures participant's beliefs about their own ability to teach the science content so that students can develop science skills and knowledge (Deehan, 2017, p. 46). The STOE measures the "participant's belief about the capacity of science teaching to overcome external factors to aid student's science learning" (Deehan, 2017, p. 46).

The ESSKT was developed by Texas Regional Collaboratives. The criterion-referenced test measures teachers' knowledge of earth and space science and estimates teachers' level of performance and deficiencies. Earth and space science was chosen as the knowledge domain because it is the eighth grade State of Texas Assessments of Academic Readiness (STAAR) science test with the highest number of missed questions (Lead4ward, 2016). Answers to test items are listed in Appendix B.

Part III was used to collect selected demographic information. Specifically, the following data were collected to describe the study's participants: age, gender, ethnicity, education level, the total number of college science courses taken, having a college degree in science (yes or no) grade level, teacher certification type (traditional or alternative), school community type (rural, urban, suburban), years of experience as a teacher, and years of experience as a science teacher.

Pilot Study

A pilot study was conducted with secondary science teachers from other parts of Texas (n = 24). Teachers were recruited, using a social media group for secondary science teachers. The majority of the participants were White, female, traditionally certified, had graduate degrees, taught in urban school districts, and did not hold science degrees. The pilot data were used to estimate the reliability of the scale scores and examine the utility of the online survey instrument. The reliability coefficients for self-efficacy and earth and space science knowledge test were 0.78 and 0.81, respectively.

Data Collection

The data were collected, using an online version of the TKSEQ. Each potential participant was informed of the study's purpose in an introductory email. A link to the online survey with a consent to participate in the study was emailed to the participants on August 1, 2017. A little over one week later (August 10, 2017), the first follow-up reminder email was sent. The final reminder was sent August 21, 2017, at which time the area had been affected by the possibility of a hurricane. Hurricane Harvey made landfall in the research area on August 25, 2017. Data collection was put on hold. On September 30, 2017, an email with the consent was sent to the participants who had been recruited in early August. Reminder emails were sent on October 14 and 30, 2017.

Data Analysis

The raw data were exported into the Statistical Package for the Social Sciences (SPSS). Due to multiple tests, the level of significance was set a priori at 0.01 to reduce the probability of making Type I errors.

Descriptive statistics were used to summarize and organize the data. Specifically, frequency and percentage distribution tables, measures of central tendency, and measures of variability were utilized (Field, 2013).

Cronbach's Coefficient Alpha (Pedhazur & Schmelkin, 1991) was used to estimate the internal consistency of the Grit Scale. Specifically, $\alpha = [k/k\text{-}1]\ [1\text{-}(\Sigma\sigma_i^2/\sigma_x^2)]$, where k is the number of items on the test, σ_i^2 is the variance of item i, and σ_x^2 is the total test variance (sum of the variances plus twice the sum of the co-variances of all possible pairs of its components, that is, $\sigma_x^2 = \Sigma\sigma_i^2 + 2\Sigma\sigma_{ij}$) was computed for each of the constructs.

An item analysis (Van Blerkon, 2009) was performed to examine item difficulty and item variance of the earth and space science knowledge test. Item difficulty, *p*, is the percentage or proportion of test takers who answer the question correctly. It ranges from 0.00 to 1.00 and is computed by, $p = (R/T)(100)$, where R = # who answer the question correctly, and T = Total number who answer the question. The percentage or proportion of test takers who answer the question incorrectly is *q*, and *pq* is the item variance; $p = 0.50$ is the best item difficulty, because it yields the maximum item variance.

A series of Independent Sample t-test (Field, 2013) was used to compare the two groups based on continuous variables. The Levene's Test was used to examine the homogeneity of variances assumption. The mean difference effect sizes were computed by dividing the mean difference by the pooled standard deviation, used to examine the practical significance of the findings, and characterized as 0.20 = small effect, 0.50 = medium effect, and > 0.80 = large effect (Cohen, 1988). Analysis of the data also included a t-test for Correlated Samples, for which, the mean difference effect size was computed by dividing the mean difference by the standard deviation of the mean difference.

A series of Pearson-Product Moment Correlation Coefficient (Field, 2013) examined the magnitude and direction of the bivariate associations between the four continuous demographic variables and the two outcome measures.

Analysis of the data also included a series of One-Way Analysis of Variance (ANOVA), which is appropriate for comparing two or more independent groups on a single dependent variable (Field, 2013). The linear model is defined by $X_{ij} = \mu + \alpha_j + \varepsilon_{ij}$, that is, Score = Grand Mean + Treatment Effect + Error Effect. The effect size is computed by $f = \sqrt{[(k-1)(F)]/N}$, where k = number of groups, F = F-ratio, and N = total sample size, and is characterized as 0.10 = small effect, 0.25 = medium effect, and > 0.40 = large effect (Stevens, 2009).

In relation to earth and space science knowledge test scores, ethnicity was a confounding variable. Thus, a One-Way Analysis of Co-variance (ANCOVA) was also performed, using ethnicity as the covariate. ANCOVA is a procedure for data analysis that adjusts the outcome measure on the basis of a confounding variable that is correlated with the dependent variable. That is, a linear relationship is assumed between the dependent variable and the covariate. It also assumes that the confounding variable does not interact with the independent variable (e.g., the intervention). It is an analysis of that portion of the variability of the dependent variable that is not accounted for by the confounding (also called extraneous or concomitant) variable. The linear model for the data is $Y_{ij} = Y + T_j + b(X_{ij} - X) + e_{ij}$, where Y_{ij} = the score of subject i under treatment j, Y = the grand mean on the dependent variable, T_j = the effect of treatment j, b = a common regression coefficient for Y on X, X_{ij} = the score on the covariate for subject i under treatment j, X = the grand mean of the covariate, and e_{ij} = the error associated with the score of subject i under treatment j. Adjusted means are computed by: Adjusted mean = Unadjusted mean for level j – b (the mean of the covariate for level j – the grand mean of the covariate), where b is the common regression coefficient (Stevens, 2009).

Summary

The data for the non-experimental study were collected by the researcher. The psychometric properties of the survey instrument were examined. The non-probability sample was not representative of the population. No causal inferences were drawn. Descriptive, univariate, and multivariate statistical techniques were used to analyze the data. Effect sizes were used to examine the practical significance of the findings.

CHAPTER IV

RESULTS

The causal-comparative/group comparison design enabled the researcher to answer the following research questions: (1) How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on self-efficacy? (2) How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on earth and space science content knowledge?

A Profile of the Subjects

The characteristic-present and comparison groups consisted of 60 and 42 secondary science teachers, respectively. The majority of the participants were White (70.60%), followed by Hispanic (22.50%), African American (2.00%), Asian (2.00%), other (2.00%), and American Indian (1.00%). For the purpose of data analysis, ethnicity was dichotomized into White and Non-white because other ethnic groups were represented by few participants. The majority of the subjects in both groups were female, White, held graduate degrees, had academic training in science, and were traditionally certified. The majority of the teachers in the characteristic-present group were from rural communities while the comparison group consisted of teachers mainly in urban school districts. Results are summarized in Table 1.

The average age of the characteristic-present group was 45.37 years old (SD = 10.83) and the comparison group average age was 45.45 years old (SD = 11.16). The average number of college science courses taken by the characteristic-present group was 17.22 (SD = 15.69); the comparison group's average was slightly higher at 17.63 (SD = 17.66). The comparison group participants had been school teachers for an average of 15.37 years (SD = 10.71) and science teachers for an average of 14.02 years (*SD* = 10.18). The teachers in the characteristic-present group had been teachers for an average of 14.78 years (*SD* = 8.04) and secondary science teachers for an average of 13.22 years (*SD* = 7.73). None of the group differences based on these four variables was statistically significant. Results are summarized in Table 2.

Table 1

Subject Profile – Categorical Variables

	Characteristic-Present Group (n=60)		Comparison Group (n=42)	
Demographic Characteristic	f	%	f	%
Gender				
Female	53.00	88.30	28.00	66.70
Male	7.00	11.70	14.00	33.30
Ethnicity				
White	46.00	76.70	26.00	61.90
Non-white	14.00	23.30	16.00	38.10
Degree				
Undergraduate	30.00	50.00	19.00	45.20
Graduate	30.00	50.00	23.00	54.80
Degree in Science				
Yes	44.00	73.30	36.00	85.70
No	16.00	26.70	6.00	14.30
Certification				
Traditional	33.00	55.00	22.00	59.50
Alternative	27.00	45.00	15.00	40.50
School community				
Urban	13.00	21.70	23.00	57.50
Suburban	10.00	16.70	8.00	20.00
Rural	37.00	61.70	9.00	22.50

Table 2

Subject Profile – Continuous Variables

	Characteristic-Present Group (n=60)		Comparison Group (n=42)	
Demographic Characteristic	Mean	SD	Mean	SD
Age	45.37	10.83	45.45	11.16
Number of college science courses taken	17.22	15.69	17.63	17.66
Number of years as a school teacher	14.78	8.04	15.37	10.71
Number of years as a science teacher	13.22	7.73	14.02	10.18

Outcome Measures

Self-efficacy

The self-efficacy survey consisted of 24 items (*Coefficient Alpha* = 0.67). The participants (n = 102) expressed their agreement/disagreement with each item, using a 4-point Likert-type scaling (4 = strongly agreed, 3 = agreed, 2 = disagreed, or 1 = strongly disagreed). The negatively stated items were reverse-coded. The mean scores for the items ranged from 1.77 to 3.38 (in Table 3). The mean of the respondents' responses to the 24 items was used to measure the scale score for self-efficacy. The scores ranged from 2.63 to 3.63 with the mean of 3.05 (*SD* = 0.21). The 24 items measure two subscales: Personal Science Teaching Efficacy beliefs, PSTE, (items 2, 4, 5, 7, 11, 16, 17, 18, 20, 21, 22, 23) and Science Teaching Outcome Expectancies, STOE, (items 1, 3, 6, 8, 9, 10, 12, 13, 14, 15, 19, 24).

Table 3

Self-Efficacy Item Mean Scores, n=102

Item	Statement	Mean**
1○	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	3.10
2▪	I will continually find better ways to teach science.	3.68
3○	When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	3.25
4▪	I know the steps necessary to teach science concepts effectively.	3.25
5*▪	I am not very effective in monitoring science experiments.	3.16
6*○	If students are underachieving in science, it is most likely due to ineffective science teaching.	2.74
7*▪	I generally teach science ineffectively.	3.30
8○	The inadequacy of a student's science background can be overcome by good teaching.	3.08
9○	The low science achievement of some students cannot generally be blamed on their teachers.	2.95
10○	When a low-achieving, child progresses in science, it is usually due to the extra attention given by the teacher.	3.06
11▪	I understand science concepts well enough to be effective in teaching secondary science.	3.40
12*○	Increased effort in science teaching produces little change in some students' science achievement.	2.71
13○	The teacher is generally responsible for the achievement of students in science.	2.86
14○	Students' achievement in science is directly related to their teachers' effectiveness in science teaching.	2.83
15○	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	3.11

Table 3 - Continued

Self-Efficacy Item Mean Scores, n=102

Item	Statement	Mean**
16*▪	I will find it difficult to explain to students why science experiment work.	3.27
17▪	I will typically be able to answer students' science questions.	3.43
18▪	I wonder if I will have the necessary skills to teach science.	1.77
19○	Effectiveness is science teaching has little influence on the achievement of students with low motivation.	2.31
20*▪	Given a choice, I would not invite the principal to evaluate my science teaching.	3.24
21*▪	When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	3.29
22▪	When teaching science, I usually welcome student questions.	3.67
23*▪	I do not know what to do to turn students on to science.	3.21
24*○	Even teachers with good science teaching abilities cannot help some kids to learn science.	2.44

*Negatively-stated item. Reversed-coded for the purpose of data analysis.
** 4 = strongly agree, 3 = agree, 2 = disagree, 1 = strongly disagree
▪ Personal Science Teaching Efficacy beliefs subscale
○Science Teaching Outcome Expectancies subscale

Earth and Space Science Knowledge

The earth and space science knowledge test had 29 items (*Coefficient Alpha* = 0.77). The test items were scored as either right (coded as 1) or wrong (coded as 0). The total score had a theoretical range of 0.00 to 29.00. The scores ranged from 8.00 to 29.00 (M = 20.30, SD = 4.68). Item difficulty and item variance indices are shown in Table 4.

Table 4

Item Analysis of Earth and Space Science Knowledge Test, n=102

Item	Question topic*	Item Difficulty	Item Variance
Item 1	Eclipse	0.59	0.24
Item 2	Phases of the moon	0.75	0.19
Item 3	Visible light	0.44	0.24
Item 4	Visible light	0.78	0.17
Item 5	Hertzsprung-Russel Diagram	0.59	0.24
Item 6	Hertzsprung-Russel Diagram	0.64	0.23
Item 7	Characteristics of stars	0.82	0.15
Item 8	Size of celestial objects	0.94	0.06
Item 9	Characteristics of nebulae and galaxies	0.72	0.20
Item 10	Electromagnetic waves	0.61	0.24
Item 11	Electromagnetic spectrum	0.83	0.14
Item 12	Redshift	0.62	0.24
Item 13	Waves	0.60	0.24
Item 14	Light year	0.47	0.25
Item 15	Light year	0.69	0.21
Item 16	Light year	0.66	0.22
Item 17	Topographic maps and satellite images	0.88	0.11
Item 18	Topographic maps	0.79	0.17
Item 19	Topographic maps	0.61	0.24
Item 20	Weathering, erosion, and deposition	0.78	0.17
Item 21	Topographic maps	0.77	0.18
Item 22	Weather	0.51	0.25
Item 23	Weather	0.90	0.09
Item 24	Atmosphere	0.64	0.23
Item 25	Indirect light	0.59	0.24
Item 26	Weather	0.98	0.02

Table 4 - Continued

Item Analysis of Earth and Space Science Knowledge Test, n=102

Item	Question topic*	Item Difficulty	Item Variance
Item 27	Winds	0.85	0.13
Item 28	Sea breezes vs. land breezes	0.73	0.20
Item 29	Plate tectonics	0.53	0.25

* See Appendix A for the statement of the question and answer options

Merging the Outcome Measures

A series of univariate analysis was performed to determine if the demographic characteristics of the participants had any impact on the outcome measures. The level of significance was set, a priori, at 0.01 to reduce the probability of making Type I Error due to performing multiple tests. In spite of unequal sample sizes, the homogeneity of variances assumption was met in all analyses.

Gender

The homogeneity of variance assumption was met, *Levene's F* = 0.74, *p* = 0.39, and t-test for independent samples, *t*(100) = 0.66, *p* = 0.51, showed that there were no statistically significant differences between females (*M* = 3.04, *SD* = 0.21) and males (*M* = 3.07, *SD* = 0.20) based on the self-efficacy scores. The effect size was small (*Cohen's d* = 0.13). The homogeneity of variance assumption was met, *Levene's F* = 0.88, *p* = 0.35, and t-test for independent samples showed that there were no statistically significant differences between females (*M* = 20.15, *SD* = 4.51) and males (*M* = 20.90, *SD* = 5.35) on the basis of the earth and space science knowledge test scores, *t*(100) = 0.66, *p* = .0.51, and the effect size was small (*Cohen's d* = 0.13). Results are summarized in Table 5.

Table 5

Comparison of Outcome Measures Based on Gender

	Female (n=81)		Male (n=21)			
	Mean	SD	Mean	SD	t	Effect Size*
Self-efficacy	3.04	0.21	3.07	0.20	0.66	0.13
Earth and Space Science Knowledge	20.15	4.51	20.90	5.35	0.66	0.13

* 0.20 = small effect, 0.50 = medium effect, > 0.80 = large effect

Ethnicity

The t-test for independent samples, $t(100) = 1.07$, $p = 0.29$, showed that there were no statistically significant differences between whites ($M = 3.06$, $SD = 0.22$) and non-whites ($M = 3.01$, $SD = 0.18$) based on the self-efficacy scores. The homogeneity of variance assumption was met, *Levene's F* = 1.95, $p = 0.17$, and the effect size was small (*Cohen's d* = 0.21). The homogeneity of variance assumption was met, *Levene's F* = 0.03, $p = 0.87$, and t-test for independent samples, $t(100) = 3.26$, $p < 0.01$, showed differences between whites ($M = 21.24$, $SD = 4.38$) and non-whites ($M = 18.07$, $SD = 4.68$) based on the earth and space science knowledge test scores were statistically significant; the effect size was medium (*Cohen's d* = 0.65). The Point-biserial correlation coefficient between earth and space science knowledge test score and ethnicity (1 = White, 2 = Non-white) was statistically significant ($r_{pb} = -0.31$, $p < 0.01$). Thus, ethnicity was considered a potential confounding variable with respect to earth and space science knowledge test score. Results are summarized in Table 6.

Table 6

Comparison of Outcome Measures Based on Ethnicity

	White (n=72)		Non-white (n=30)			
	Mean	SD	Mean	SD	t	Effect Size*
Self-efficacy	3.06	0.21	3.01	0.18	1.07	0.21
Earth and Space Science Knowledge	21.24	4.38	18.07	4.68	3.26**	0.65

* 0.20 = small effect, 0.50 = medium effect, > 0.80 = large effect

** $p < 0.01$

College Degree

The homogeneity of variance assumption was met, *Levene's F* = 2.66, *p* = 0.11, and t-test for independent samples, *t*(100) = 0.25, *p* = 0.81, showed that there were no statistically significant differences between holders of undergraduate (*M* = 3.05, *SD* = 0.18) and graduate (*M* = 3.04, SD = 0.23) degrees based on the self-efficacy scores. The effect size was negligible (*Cohen's d = 0.05*). Additionally, t-test for independent samples showed that there were no statistically significant differences between undergraduate degree holders (*M* = 20.49, *SD* = 5.33) and graduate degree holder (*M* = 20.13, *SD* = 4.02) based on the earth and space science knowledge test scores, *t*(100) = 0.38, *p* = 0.70. The homogeneity of variance assumption was met, *Levene's F* = 3.92, p = 0.05, and the effect size was negligible (Cohen's d = 0.08). Results are summarized in Table 7.

Table 7

Comparison of Outcome Measures Based on College Degree

	Undergraduate (n=49)		Graduate (n=53)			
	Mean	SD	Mean	SD	t	Effect Size*
Self-efficacy	3.05	0.18	3.04	0.23	0.25	.05
Earth and Space Science Knowledge	20.49	5.33	20.13	4.02	0.38	.08

* 0.20 = small effect, 0.50 = medium effect, > 0.80 = large effect

Science Degree

The homogeneity of variance assumption was met, *Levene's F* = 0.98, *p* = 0.33, and t-test for independent samples, *t*(100) = 0.65, *p* = 0.51, showed no statistically significant differences between teachers with science degrees (*M* = 3.05, *SD* = 0.22) and teachers without science degrees (*M* = 3.02, *SD* = 0.18) on the basis of the self-efficacy scores. The mean difference effect size was 0.13. Differences between science degree holders (*M* = 20.49, *SD* = 4.77) and teachers who did not have a science degree (*M* = 19.64, *SD* = 4.36) based on the earth and space science knowledge test scores were not statistically significant, *t*(100) = 0.75, *p* = 0.45. The homogeneity of variance assumption was met, *Levene's F* = 0.48, *p* = 0.49, and the mean difference effect size was 0.15. Results are summarized in Table 8.

Table 8

Comparison of Outcome Measures Based on Science Degree

	Degree in Science (n=80)		No Degree in Science (n=22)			
	Mean	SD	Mean	SD	t	Effect Size*
Self-efficacy	3.05	0.22	3.02	0.18	0.65	0.13
Earth and Space Science Knowledge	20.49	4.77	19.64	4.36	0.75	0.15

* 0.20 = small effect, 0.50 = medium effect, > 0.80 = large effect

Teacher Certification

The homogeneity of variance assumption was met, *Levene's F* = 0.42, *p* = 0.52, and t-test for independent samples showed no statistically significant differences between teachers who had a traditional certification (*M* = 3.02, *SD* = 0.21) and teachers who had an alternative certification (*M* = 3.09, *SD* = 0.20) based on the self-efficacy scores, *t*(95) = 1.63, *p* = 0.11. The mean difference effect size was 0.33. Furthermore, there were no statistically significant differences between teachers with traditional certifications (*M* = 20.13, *SD* = 4.52) and teachers with alternative certifications (*M* = 20.79, *SD* = 4.72) on the basis of the earth and space science knowledge test scores, *t*(95) = 0.70, *p* = 0.49. The homogeneity of variance assumption was met, *Levene's F* = 0.07, *p* = 0.79, and the mean difference effect size was 0.14. Five participants did not provide the demographic informtion. Results are summarized in Table 9.

Table 9

Comparison of Outcome Measures Based on Teacher Certification Type

	Traditional (n=55)		Alternative (n=42)			
	Mean	SD	Mean	SD	t	Effect Size*
Self-efficacy	3.02	0.21	3.09	0.20	1.63	0.33
Earth and Space Science Knowledge	20.13	4.52	20.79	4.72	0.70	0.14

* 0.20 = small effect, 0.50 = medium effect, > 0.80 = large effect

School District Setting

The participating teachers represented urban, suburban, and rural school districts. The homogeneity of variances assumption was met for the self-efficacy (*Levene's F* = 2.74, $p = 0.07$) and the earth and space science knowledge test scores (*Levene's F* = 0.24, $p = 0.79$). Based on the self-efficacy scores, $F(2, 97) = 0.78$, $p = 0.46$, and the earth and space science knowledge test scores, $F(2, 97) = 2.47$, $p = 0.09$, group differences were not statistically significant, and the mean difference effect sizes were 0.12 and 0.22, respectively. Two participants did not provide the school district type. Descriptive statistics are summarized in Table 10.

Table 10

Comparison of Outcome Measures Based on School District Setting

		Self-Efficacy		Earth and Space Science Knowledge	
	N	Mean	SD	Mean	SD
Urban	36	3.06	0.24	19.06	4.80
Suburban	18	3.09	0.22	21.00	4.54
Rural	46	3.02	0.17	21.20	4.26

Age, Science Course, and Experience

A series of Pearson Product Moment Correlation Coefficient analysis was performed to examine the magnitude and directions of the simple/bivariate associations between age in years, number of college science courses taken, years of experience as a teacher, and years of experience as a science teacher (Table 2) and the outcome measures of the self-efficacy and the earth and space science knowledge scores. None of the association was statistically significant at the 0.01 level. Results are summarized in Table 11.

Table 11

Simple Correlation Matrix*

	Self-efficacy	Earth and Space Science Knowledge
Age	-0.02	0.24
Number of Science Courses	0.03	0.09
Number of years as a teacher	0.00	0.16
Number of years as a science teacher	0.08	0.22

* None of the associations was statistically significant at the 0.01 level

Group Comparisons

Analysis of the data showed that the outcome measure of the self-efficacy had not been affected by the demographic characteristics of the participants; thus, they were ruled out as the potential confounding variables. The data were merged. The homogeneity of variance assumption was met, *Levene's F* = 0.30, p = 0.56, and t-test for independent samples showed no statistically significant differences between the characteristic-present group (M = 3.03, SD = 0.22) and the comparison group (M = 3.07, SD = 0.20) based on the self-efficacy scores, $t(100)$ = 0.77, p = 0.45. The mean difference effect size was 0.15. Results are summarized in Table 12.

Table 12

Comparison of Characteristic-present and Comparison Groups Based on Self-efficacy

	Characteristic-Present Group (n=60)		Comparison Group (n=42)			
	Mean	SD	Mean	SD	t	Effect Size*
Self-efficacy	3.03	0.21	3.07	0.20	0.77	0.15

* 0.20 = small effect, 0.50 = medium effect, > 0.80 = large effect

Self-efficacy was further divided into two subscales: Personal Science Teaching Efficacy beliefs (PSTE) and Science Teaching Outcome Expectancies (STOE). The homogeneity of variance assumption was met, *Levene's F* = 0.03, p = 0.86, and t-test for independent samples showed that there were no statistically significant differences between the characteristic-present group (M = 3.21, SD = 0.26) and comparison group (M = 3.22, SD = 0.27) on the basis of the Personal Science Teaching Efficacy, $t(100)$ = 0.23, p = 0.82, and the effect size was negligible (*Cohen's d* = 0.03). Likewise, the homogeneity of variance assumption was met on the Science Teaching Outcome Expectancies, *Levene's F* = 0.25, p = 0.62, and t-test for independent samples, $t(100)$ = 1.06, p = 0.29, showed that there were no statistically significant differences between the characteristic-present group (M = 2.85, SD = 0.23) and comparison group (M = 2.90, SD = 0.26). The effect size was small (*Cohen's d* = .21).

For all subjects, the PSTE score (M = 3.22, SD = 0.26) were higher than the STOE scores (M = 2.87, $SD = 0.24$). The difference was statistically significant, $t(101)$ = 12.60, p < 0.01, and the mean difference effect size was large (*Cohen's d = 1.25*).

In analyzing the data for the earth and space science knowledge test scores, ethnicity was treated as a confounding variable and used in adjusting the outcome measures. An analysis of co-variance (ANCOVA) showed the differences between the characteristic-present group (*Observed Mean* = 21.03, *Adjusted Mean* = 20.82, *SD* = 4.16) and the comparison group (*Observed Mean* = 19.26, *Adjusted Mean* = 19.48, *SD* = 5.20) were not statistically significant, $F(1, 99) = 2.18$, $p = 0.14$. The homogeneity of variance assumption was met, *Levene's F* = 1.61, $p = 0.21$. The mean difference effect size was 0.19, favoring the characteristic-present group. Results are presented in Table 13.

Table 13

Comparison of Characteristic-present and Comparison Groups Based on Earth and Space Science Knowledge

	Characteristic-Present Group (n=60)		Comparison Group (n=42)			
	M1/M2*	SD	M1/M2*	SD	F	Effect Size**
Earth and Space Science Knowledge	21.03/20.81	4.16	19.26/19.48	5.20	1.91	0.19

* M1/M2 = Observed Mean/Adjusted Mean

** 0.20 = small effect, 0.50 = medium effect, > 0.80 = large effect

Summary

The researcher had hypothesized that secondary school teachers who received intensive, explicit science content professional development would outperform the comparison group based on the self-efficacy and the earth and space science knowledge test scores. The results of the study did not support the hypotheses.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The purpose of this ex-post facto, causal-comparative research was to determine if secondary science teachers who received intensive, explicit professional development would have higher self-efficacy and science content knowledge than would secondary science teachers who were not part of the professional development program.

Summary of the Study

Sixty (60) teachers elected to take a year-long professional development focusing on earth and space science topics. Their content knowledge in earth and space science and self-efficacy scores were compared to a comparison group ($n = 42$) of educators from the same area who did not choose to partake in the course in order to test the hypotheses that teachers who receive intensive, explicit professional development have higher teacher self-efficacy and earth and space science content knowledge than do teachers who do not receive the intervention. The following research questions guided the study:

1. How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on self-efficacy?
2. How do secondary school teachers who receive intensive, explicit science content professional development and those who do not receive the intervention differ on earth and space science content knowledge?

The self-efficacy survey consisted of 24 items and used a 4-point Likert-type scaling (4 = strongly agreed, 3 = agreed, 2 = disagreed, or 1 = strongly disagreed). The negatively stated items were reverse-coded. The mean scores for the items ranged from 1.77 to 3.38. The mean of the respondents' responses to the 24 items was used to measure the scale score for self-efficacy.

The scores ranged from 2.63 to 3.63 with the mean of 3.05 (*SD* = 0.21). The 24 items measure two subscales: Personal Science Teaching Efficacy beliefs, PSTE, and Science Teaching Outcome Expectancies, STOE.

The earth and space science knowledge test had 29 items (*Coefficient Alpha* = 0.77). The total score had a theoretical range of 0.00 to 29.00. The scores ranged from 8.00 to 29.00 (*M* = 20.30, *SD* = 4.68). An item analysis demonstrated that 30% of the test questions were difficult and 24% garnered an item difficulty of 0.82 and above, making them easier to answer.

Conclusions

The results did not support the researcher's hypotheses that secondary school teachers who received intensive, explicit science content professional development would outperform the comparison group based on the earth and space science knowledge test and self-efficacy scores. The Personal Science Teaching Efficacy (PSTE) beliefs were scored higher than did the Science Teaching Outcome Expectancies (STOE) among all study participants.

Discussion

Teachers need ongoing science professional development in order to keep up with new scientific and technological advancements. The content of the Texas Regional Collaboratives (TRC) training was based on recommendations from the TEA. Teachers were not included in the meetings in which content decisions were made. Teachers' prior knowledge or style of learning was not taken into account when the course was designed. Item analysis showed that only 30% of the earth and space science content knowledge test items, which had been designed by the TRC, was difficult. There were 12 questions, representing nearly half the test that 70% of the participants answered correctly. Luft and Hewson (2014) asserted that professional development programs must recognize teachers themselves are responsible for their professional development. Professional development must involve active learning and reflection (Desimone, 2011; Luft & Hewson, 2014). Teachers were left out of the design and creation of this program. Perhaps if they were involved, there would have been a difference in knowledge between the two groups.

Professional development should focus on teacher learning, not on the structure of the program (Desimone, 2011). Although the TRC's mission is to provide teachers with researched-based professional development to assist with the implementation of the Texas Essential Knowledge and Skills (TEKS) in the teachers' classroom, there is no classroom observations, reflection, or mentoring. Professional development programs need to incorporate time and a mechanism for teacher self-reflection (Deehan, 2017). Reflection would enable a teacher to go through all of the experiential learning cycle (Kolb, 1984). Situating part of the professional development in a teacher's classroom would be cost-prohibited; however, videotaping a teacher's teaching would allow a teacher to witness his/her instruction. Desimone (2011) asserted that learning in a teacher's own classroom through reflection and observation can be very powerful. Professional development programs can design instructional activities to incorporate the tapes and allow the teachers to analyze their instruction with a mentor.

Luft and Hewson (2014) stated that science professional development should focus on a discipline and various domains. Disciplines are specialized areas of study (Gardner, 1972). Domains are the objects that are studied such as the sun or watersheds (Gardner, 1972). The TRC professional development focused on Earth Science and Space Science. There were just too many domains to effectively cover in the 100-hour professional development. In order to be effective, the focus must be on a limited number of domains.

Tschannen-Moran and McMaster (2009) asserted that the majority of instructional improvement programs fail because they do not take into account what motivates teachers to engage in professional development and the process by which change in teachers typically take place. Although the results of this study did not show any statistically significant differences between the two groups on either earth and space science knowledge or self-efficacy, the premise of the investigation suggested motivation; that is, the characteristic-present group members chose to take advantage of the opportunity and took the year-long professional development, whereas their peers decided not to. Darling-Hammond et al. (2009) stressed that teachers in the United States have fewer opportunities to participate in extended professional development programs than their peers in other countries. The characteristic-present group members had 100 hours with their peers. The TRC became a community of practice for the teachers. Lave and Wenger (1991) described communities of practice as “a system of relationships between people, activities, and the world, developing over time” (p. 26). A community of practice has also been defined as a group of people “who share a concern or a passion for something they do and learn how to do it better as they interact regularly” (Wegner & Wegner-Trayner, 2015, p. 1). Members of a community of practice have a shared history, shared domain of interest, and mutual collaboration and engagement that are constructed through their interactions and collaborations.

Deehan (2017) conducted a comprehensive review of the methods and findings of 25 years of research, using the STEBI – A. He found that the science intervention programs that incorporated inquiry instruction, modeling instruction, and deep content had the largest Personal Science Teaching Efficacy (PSTE) effect size. The present study’s TRC professional development incorporated these practices; however, the PSTE effect size was negligible. One reason for the difference can be that the TRC is a tertiary partnership, which was not present in the studies that Deehan had investigated. The TRC is its own entity and does not answer to the State Board of Education or any school district. Teachers choose to take it and are not forced to participate.

Unlike the PSTE, Deehan's review did not yield any consistent pedagogical trends for the Science Teaching Outcome Expectancies (STOE). The top four instruction practices netted effect sizes, ranging from 0.38 to 0.80. This study's STOE had an effect size of 0.21. Deehan asserted that STOE has lower mean scores and lower reliability than does PSTE (2017). This study had the similar results.

Deehan's review also demonstrated that teachers' PSTE scores tend to be higher than are STOE scores. This study's PSTE scores (M = 3.22, SD = 0.26) were higher than the STOE scores (M = 2.87, SD = *0.24*), and the effect size was large, which was similar to 75% of the studies Deehan had investigated in his meta-analytical study. One reason for the difference is the latent variables in the STOE subscales, such as other science teachers, socio-economic status of the students in the school, and school context (e.g., Title 1). Since STOE is concerned with the science teachers' perception of delivering science instruction in a way to overcome external variables that their students bring to class, perhaps science teachers have a touch of cynicism.

Science educators are the essential component in having a scientifically literate populous, which is the goal of most countries on the planet (Luft & Hewson, 2014). Being scientific literate allows individuals greater understanding of the issues they encounter daily in the media, govt, and personal life. Teachers need to have both the content knowledge and the belief that their teaching can make a difference in their students' lives.

Implications

The Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancies STOE score disparity must be considered when designing science professional development programs. The STOE measures a teacher's belief about his or her own science teaching to aid students who have external factors such as low socioeconomic status or a learning disability. In 1965, the Elementary and Secondary Education Act (ESEA) was passed as part of President Johnson's "War on Poverty." He wanted to prevent poverty, but in the fifty-three years since it was passed, the United States has not won the war; in fact, it is losing it. The US has a higher rate of child poverty (51%) than any other developed nation (Budge & Parrett, 2018).   Budge and Parrett (2018) asserted that teachers' jobs have become more challenging because of the increasing rate of child poverty; therefore, it is imperative that teachers need to believe that their science teaching can overcome those factors. Strategies are needed to improve the STOE; for example, by providing appropriate professional development opportunities and understanding the impact of poverty on the teaching and learning process.

Only 30% of the teachers demonstrate improvement in their classroom practices after receiving the professional development (The New Teacher Initiative, 2015). Professional development programs must include opportunities for reflection, either in classroom training or videotaping the lesson. The reflective framework should be based on critiquing the participant's practice and adjusting it, not dismantling it (Deehan, 2017). Science professional development programs must be narrowly focused. Only one discipline should be concentrated at a time. The professional development that the characteristic-present group received included all Texas middle school science standards.

The success of professional development programs depends on identification and understanding teacher's knowledge and perceptions, prior to the creation of the program. Therefore, schools, districts, third-party providers, and states need to focus on their teachers' needs and take them into consideration in designing and implementing professional development programs. Teachers with a high level of efficacy frequently participate in professional development to improve their instructional practices in order to increase their students' learning (Zee & Koomen, 2016).

In order to raise teacher's self-efficacy, professional development facilitators need to allocate time for teachers to practice inquiry and other scientific skills. Professional development facilitators also need to be skilled in mentoring adults. The study's director of the TRC professional development program in the Victoria Crossroads and Coastal Bend acted as a mentor for both groups; however, she could not effectively mentor each member by herself.

Recommendations for Future Research

The study's delimitations, limitations, assumptions, and findings offer opportunities for further research. Longitudinal studies are needed to determine if teachers' new knowledge is translated into the teaching of earth and space science; consequently, affecting students' academic achievement, self-efficacy, attitudes, and academic performance. It would be interesting to compare randomly selected teachers with those who are self-selected to explore if the nature of the participation may affect teachers' self-efficacy and content knowledge. Future research on professional development must include teacher reflection, beliefs, and classroom practices. Teachers have a lifetime of experiences as learners as well as skills to be educators, which influence learning in professional development settings. Conducting qualitative studies on teachers' perspectives of the TRC professional development are recommended; for example, why some experienced teachers continue attending the TRC program on a yearly basis. Future studies benefit from multiple administration of the STEBI-A in an attempt to examine development changes in self-efficacy among teachers. It would also be interesting to examine other outcome measures which have the potential to be affected by the TRC program.

Personal Reflections

I was stunned by the results of this study. I was sure there would be a difference in the characteristic-present group's content knowledge and self-efficacy, compared to the comparison group. These teachers are the people in the area that provide professional development classes that other teachers flock to because of the opportunity to learn. These teachers are the people that give freely of their time to help their fellow teachers with pedagogical issues. These are the teachers whose students pass the STAAR test with the highest passing rates in the region.

Over 100 teachers in the comparison group started the survey, but only 42 finished it. I was perplexed. The members of the characteristic-present group helped recruit teachers for the comparison group. Because of that relationship, some in the comparison group shared their opinions about the study with their peers in the characteristic-present group. Some of the members of the characteristic-present group disclosed to me what was revealed to them without identifying the persons who had talked to them. I realized some did not finish the survey due to the complexity of the Earth and Space Science Knowledge Test. On the other hand, there were earth and space science teachers who thought the test was easy and completed the survey. This could have resulted in a homogeneous sample, which may explain the lack of variation and statistically significant results.

I know that there were many members of the characteristic-present group that have chosen to be involved with the TRC professional development for over 15 years. But, what motivates them to do that? Yes, there is a small stipend that the teachers earn. It equals to about $6.00 an hour; therefore, there must be some other reason that they continue to give up 100 hours of their time to attend. I would like to continue to research this group and find out why they stay involved and how the professional development is impacting their science classrooms. This intrigues me. I want to focus on the relationship between these teachers' classroom behavior and their student outcomes, such as students' self-efficacy beliefs, motivation, and academic achievement.

When the Elementary and Secondary Education Act was reauthorized in 2015, not only was its name changed to Every Student Succeeds Act (ESSA), but also there was a change to the funding of the Texas Regional Collaboratives. Before the 2015 bill, there was the inclusion of three little words that were instrumental in the distribution of federal monies to the states for education. The words were "math and science," and without them, states could allocate the monies to any program they wanted. After June 2018, the Texas Science and Mathematics Collaboratives will no longer have funding. The professional development programs that were provided in the Victoria Crossroads and Coastal Bend for over twenty-years will cease which will create a void in the mathematics and science professional development opportunities in the area. This vacuum will evidently trickle down to impact student achievement. Teachers directly affect student learning; therefore, teacher quality is paramount. Without science professional development opportunities in the region, how will teachers acquire a new skill and learn about new pedagogical practices? How can teachers develop a community of practice to support them?

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Appendix A

Teacher Knowledge and Self-Efficacy Questionnaire (TKSEQ)

Part I – Science Teaching Efficacy Belief Instrument-A (STEBI-A)

Please indicate your level of agreement or disagree with the following statements.
SA – Strongly agree
A – Agree
D – Disagree
SD – Strongly disagree

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA	A	D	SD
2. I will continually find better ways to teach science.	SA	A	D	SD
3. When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	SA	A	D	SD
4. I know the steps necessary to teach science concepts effectively.	SA	A	D	SD
5. I am not very effective in monitoring science experiments.	SA	A	D	SD
6. If students are underachieving in science, it is most likely due to ineffective science teaching.	SA	A	D	SD
7. I generally teach science ineffectively.	SA	A	D	SD
8. The inadequacy of a student's science background can be overcome by good teaching.	SA	A	D	SD
9. The low science achievement of some students cannot generally be blamed on their teachers.	SA	A	D	SD
10. When a low-achieving, child progresses in science, it is usually due to the extra attention given by the teacher.	SA	A	D	SD

11. I understand science concepts well enough to be effective teaching secondary science. SA A D SD

12. Increased effort in science teaching produces little change in some students' science achievement. SA A D SD

13. The teacher is generally responsible for the achievement of students in science. SA A D SD

14. Students' achievement in science is directly related to their teachers' effectiveness in science teaching. SA A D SD

15. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher. SA A D SD

16. I will find it difficult to explain to students why science experiment work. SA A D SD

17. I will typically be able to answer students' science questions. SA A D SD

18. I wonder if I will have the necessary skills to teach science. SA A D SD

19. Effectiveness is science teaching has little influence on the achievement of students with low motivation. SA A D SD

20. Given a choice, I would not invite the principal to evaluate my science teaching. SA A D SD

21. When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand it better. SA A D SD

22. When teaching science, I will usually welcome student questions. SA A D SD

23. I do not know what to do to turn students on to science. SA A D SD

24. Even teachers with good science teaching abilities cannot help kids to learn science. SA A D SD

Part II – Earth and Space Science Knowledge Test (ESSKT)

The 29-item test is designed to measure your earth and space science knowledge. Please choose the correct answer for each of the questions.

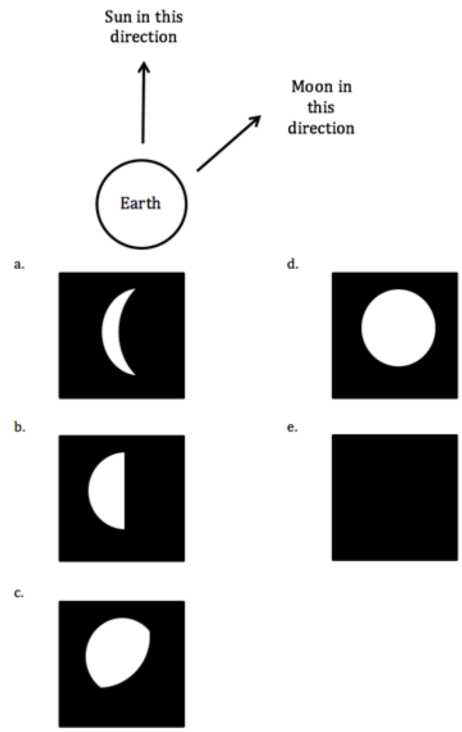
Q1. Below are six statements about an eclipse of the Moon. These statements may be correct or incorrect.

1. A lunar eclipse occurs when the Moon passes between Earth and the Sun.
2. A lunar eclipse occurs when the Sun passes between the Earth and the Moon.
3. A lunar eclipse occurs when the Earth passes between the Sun and the Moon.
4. A lunar eclipse occurs when there is a New Moon.
5. A lunar eclipse occurs when there is a Full Moon.
6. A lunar eclipse occurs when there is a Crescent Moon.

Which of the following indicates those statements that are correct about a lunar eclipse?

1. Statements 1 and 4
2. Statements 2 and 5
3. Statements 3 and 5
4. Statements 1 and 6
5. Statements 3 and 6

Q2. If you could look down from space at Earth from far above its north pole on a particular day, the Sun and Moon would be in the directions shown by the arrows in the picture below. What would the Moon look like to a person on Earth facing the Moon?



1. A
2. B
3. C
4. D
5. E

Q3. Below are some properties or behaviors of visible light.

1. Visible light is part of the electromagnetic spectrum.
2. Visible light travels in a straight line.
3. Visible light has a wavelength between 400 nm and 700 nm.
4. Visible light reflects off of objects.
5. Visible light refracts when it changes mediums.
6. Visible light exhibits properties of both waves and particles.

Which properties or behaviors are most critical for students to understand when they are learning about the phases of the Moon?

1. Statements 1 and 6
2. Statements 1 and 2
3. Statements 1 and 4
4. Statements 2 and 4
5. Statements 2 and 5

Q4. Visible light waves are incapable of passing through a wall while radio waves are capable due to which important difference in their properties?

1. Visible light waves can be seen with the human eye while radio waves are invisible.

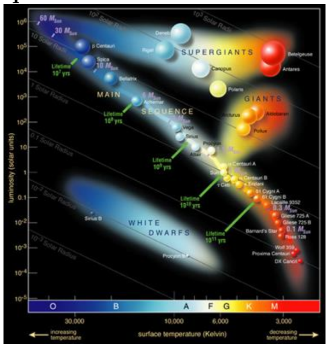
2. Visible light is part of the electromagnetic spectrum while radio waves are not.

3. Visible light waves have much shorter wavelengths than radio waves.

4. Radio waves are created by electric or magnetic processes.

5. Radio waves are man-made and designed to penetrate into buildings.

Q5. Below is a representation of the Hertzprung-Russel Diagram. Use the diagram to answer the question below.



If you were to increase the temperature of a particular star and leave its size constant, its location on the H-R diagram will move

1. up and to the left

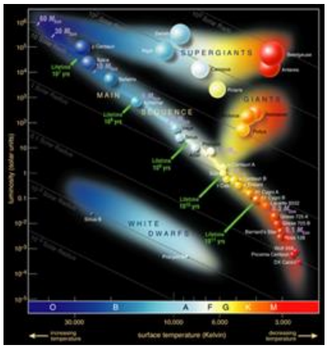
2. up and to the right

3. down and the left

4. down and to the right

5. none, its position would remain the same

Q6. Below is a representation of the Hertzprung-Russel Diagram. Use the diagram to answer the question below.



Compared to Polaris, Betelgeuse is

1. hotter and more luminous
2. hotter and less luminous
3. cooler and more luminous
4. cooler and less luminous

Q7. Which of the following is true of stars on the main sequence?

1. They all have the same brightness.
2. They are fusing hydrogen into helium.
3. They are fusing helium into hydrogen.
4. They are fusing helium into carbon.
5. They have no nuclear energy sources in their centers.

Q8. Which of the following correctly lists the objects in order from smallest to largest?

1. A nebula, the Moon, the Earth, the Sun, the Universe, the Milky Way Galaxy.
2. The Milky Way Galaxy, the Moon, the Sun, the Universe, the Earth, a nebula.
3. The Moon, the Earth, the Sun, a nebula, the Milky Way Galaxy, the Universe.
4. The Sun, the Moon, the Milky Way Galaxy, a nebula, the Earth, the Universe.

Q9. Which of the following correctly describes nebulae and galaxies?

1.

Nebulae	Galaxies
• contain dust • may develop into stars • have shorter lifespans than most galaxies • may form when stars develop or when they implode • classified as spiral, elliptical and irregular	• do not contain dust • contain stars • contain nebulae • often found in clusters • held together by gravitational forces • classified into emission, HII region, supernova remnant and dark

2.

Nebulae	Galaxies
• contain dust • may develop into a stars • have shorter lifespans than most galaxies • may form when stars develop or when they implode • classified into emission, HII region, supernova remnant and dark	• contain dust • contain stars • contain nebulae • often found in clusters • classified as spiral, elliptical and irregular • held together by gravitational forces

3.

Nebulae	Galaxies
• contain dust • have longer lifespans than most galaxies • may contain galaxies • may form when stars develop or when they implode • classified into emission, HII region, supernova remnant and dark	• contain dust • contain stars • often found in clusters • classified as spiral, elliptical and irregular • held together by gravitational forces

4.

Nebulae	Galaxies
• do not contain dust • may develop into stars • have shorter lifespans than most galaxies • classified into emission, HII region, supernova remnant and dark • held together by gravitational forces	• contain dust • contain stars • contain nebulae • often found in clusters • classified as spiral, elliptical and irregular • may form when stars develop or when they implode

Q10. Electromagnetic waves can be distinguished from mechanical waves. The distinction is based on the fact that electromagnetic waves

1. Can travel through materials and mechanical waves cannot.
2. Come in a range of frequencies and mechanical waves exist with only certain frequencies.
3. Can travel through a region void of matter and mechanical waves cannot.
4. Cannot transport energy and mechanical waves can transport energy.
5. Have infinite speed and mechanical waves have a finite speed.

Q11. The electromagnetic spectrum is used to study the universe because

1. Most objects in the universe emit visible light.
2. The atmosphere of earth does not interfere with incoming radiation.
3. Each type of object in the universe only emits one type of radiation.
4. Different types of radiation provide different information about objects.

Q12. A scientist studying an object in space observes "redshift." She can then conclude which of the following about the object being studied?

1. The object is getting hotter
2. The object is getting cooler
3. The object is moving towards the earth
4. The object is moving away from earth

Q13. Which of the following is true about the relationship between wavelength and frequency? Assume the velocity of the wave is kept constant

1. There is no relationship between wavelength and frequency
2. The relationship varies depending on wave type
3. They are inversely proportional
4. They are directly proportional

Q14. If light takes 8 minutes to reach the Earth from the Sun and 5 hours to reach Pluto from the sun, what is the distance from the sun to Pluto?

1. 5 AU
2. 37.5 AU
3. 37.5 ly
4. 5 ly
5. 0.6 ly

Q15. Which of the following represents the best way to model a light year?

1. Using a meter stick to measure the length of the hallway
2. Using a long tape measure to length of the hallway
3. Explaining how an odometer in a car works
4. Using a constant motion vehicle to time how far it travels in a minute

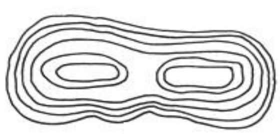
Q16. A light year is equal to

1. The distance between the Sun and the Earth.
2. The time it takes light to travel between the Earth and the center of the Universe.
3. The distance light travels in one Earth year.
4. The time it takes light to travel a certain distance.

Q17. Topographic maps and satellite images are both useful in predicting how features may be reshaped by weathering and/or erosion. Which of the following is a piece of information not provided or observable on either topographic maps or satellite images?

1. Where bodies of water are found
2. The slope of the land
3. Relative amount of vegetation
4. Soil composition
5. Large rock outcroppings

Q18. Shown below is a simplified topographic map.



Which of the following profiles best matches the map shown above?

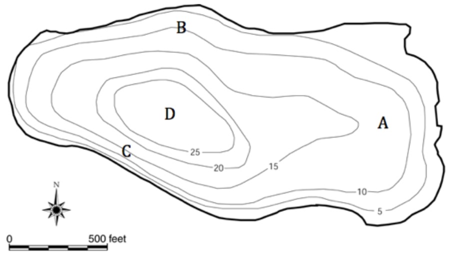
(1) 

(2) 

(3) 

(4) 

Q19. Shown below is a simplified topographic map with four locations marked (A-D)



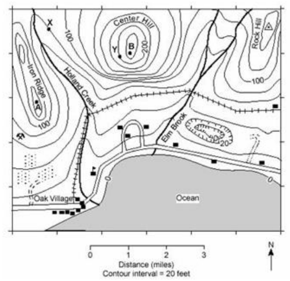
All other factors being equal, which location would you expect to experience the most weathering and erosion following a heavy rainstorm (assume no rain shadow exists)?

1. A
2. B
3. C
4. D

Q20. If mountains erode over long periods of time, what can happen?

1. The mountains decrease in height
2. Parts of mountains become steeper
3. Valleys decrease in depth
4. Only 1 and 3 can happen
5. 1, 2, and 3 can all happen

Q21. On the map, just to the East of Elm Brook and slightly North of the Ocean is an oval-shaped structure. This structure is most likely a



1. Depression

2. Hill

3. Cliff

4. Parking lot

Q22. During an investigation of factors that may be used to forecast weather conditions, students collect daily data on four factors (air pressure, temperature, rainfall and cloud cover) over a period of a month. The best use of these data would be to

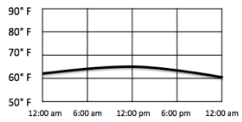
1. Overlay graphics of the data to look for consistent patterns among the factors.

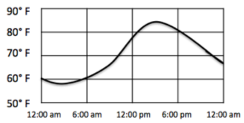
2. Create separate graphs for each factor to better sort out the independent contribution of each factor to the weather.

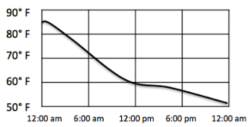
3. Average the measurements for each factor to get a representative data set for the month.

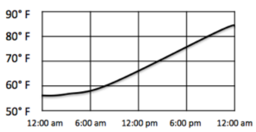
4. Only use those data that support their hypothesis since contradictions are possible due to measurement error.

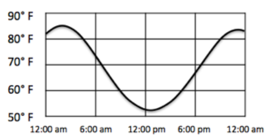
Q23. The graphs below show the air temperature readings for five different days. On which day was the sky most likely covered by clouds daytime and nighttime?

1. 

2. 

3. 

4. 

5. 

Q24. The density of the Earth's atmosphere decreases with altitude. This is because

1. Cosmic radiation from the Sun blows the upper atmosphere away.

2. The weight of the air above any point compresses the air.

3. Humidity is higher at Earth's surface.

4. Winds at the surface blow more slowly than at high altitudes allowing the air to become more concentrated.

Q25. The equatorial regions receive more solar energy than the polar regions because the equatorial regions

1. Have more vegetation to absorb sunlight.

2. Have days with more hours of light.

3. Receive more sunlight over the course of a year.

4. Receive sun rays closest to vertical.

Q26. When a warm air mass and a cooler air mass converge at the Earth's surface which of the following generally occurs?

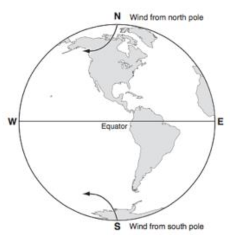
1. The sky becomes clear.

2. Winds die down.

3. Cloud formation decreases.

4. Stormy weather patterns develop.

Q27. The diagram below illustrates the westward deflection of air moving from the poles towards the equator.



The primary cause of this global deflection is

1. The shape, size, and locations of land masses.

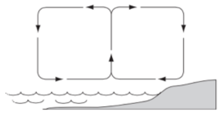
2. The shape, size, and locations of oceans.

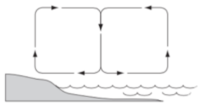
3. The difference in total land mass of the two hemispheres.

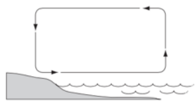
4. The tilt of earth's axis relative to its orbital plane.

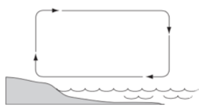
5. The rotation of the earth on its axis.

Q28. Which diagram best models the movement of coastal air during the afternoon?

1. 

2. 

3. 

4. 

Q29. Models are often used to study complex natural systems. Which of the following is one limitation of studying systems such as plate tectonics with models?

1. Changes occur very slowly requiring years to allow the model to develop.
2. Natural systems do not have variables, which could be manipulated or controlled.
3. It is impossible to predict how any of the components of systems will react to change.
4. It is difficult to include all of the important interactions due to the high number of variables.

Part III – Demographic Information

Please provide the following demographic information which will be used to describe the participants.

Age: _____

Gender:

1. Female
2. Male

Ethnicity:

1. White (non-Hispanic)
2. Hispanic
3. African American
4. American Indian or Alaska Native
5. Asian
6. Native Hawaiian or other Pacific Islander
7. Other

Education Level:

1. Bachelor's degree
2. Master's degree
3. Doctoral degree

Do you have a college degree in science?

1. Yes
2. No

Number of college science courses taken: _____

Number of years as a school teacher: _____

Number of years as a science teacher: _____

Teacher Certification Type

1. Traditional
2. Alternative

What type of community does your school serve?

1. Urban
2. Suburban
3. Rural

Appendix B

Earth and Space Science Knowledge Test (ESSKT) Key

Q1. 3

Q2. 1

Q3. 4

Q4. 3

Q5. 1

Q6. 3

Q7. 2

Q8. 3

Q9. 2

Q10. 3

Q11. 4

Q12. 4

Q13. 3

Q14. 2

Q15. 4

Q16. 3

Q17. 4

Q18. 1

Q19. 3

Q20. 5

Q21. 1

Q22. 1

Q23. 1

Q24. 2

Q25. 4

Q26. 4

Q27. 5

Q28. 4

Q29. 4