WHAT DO THEY KNOW ABOUT SCIENCE? INITIAL CERTFICATION TESTING OF ELEMENTARY PRESERVICE TEACHER CANDIDATES

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Literature indicates that science content knowledge has long presented difficulties for preservice elementary teachers. Analyses of 473 scores from participants' attempts on an elementary certification exam, the TExES EC-6 Core Subjects, Science (804), were analyzed for this study to determine the impact of a physical science intervention that included demonstration lessons, microteaching, and reflection as part of a science methods course on science content knowledge. Analyses of scores for participants making repeat attempts to pass indicated that scores were higher for attempts made after participation in the physical science intervention than attempts made before participation. Of 104 participants who made initial unsuccessful attempts and repeat attempts, the 89 attempts made after participation in the physical science intervention had a mean scaled score of 238.24 (SD = 14.93) while the mean score for the 15 attempts made before participation in the intervention was 219.73 (SD = 20.04). The difference between the mean scaled score for these two groups was statistically significant, t = -4.21, df = 102, p<.001. Score reports from Hispanic/Latino and from White/Non-Hispanic participants who passed on the first attempt (n = 85, MS = 259.82, SD = 12.04 and n = 226, MS = 264.12, SD = 11.92, respectively) were compared to score reports from Hispanic/Latino and White/Non-Hispanic participants who were not successful on the initial attempt and made repeat attempts (n = 32, MS = 235.31, SD = 14.86 and n = 51, MS = 240.06, SD = 15.13). Analysis indicated that there was

statistically significant difference in mean scaled scores between the groups who passed the initial attempt (t = -2.83, df = 309, p = .005) while there was no statistically significant difference in the mean scaled scores when comparing Hispanic/Latino and White/Non-Hispanic participants completing multiple attempts (t = -1.40, df = 81, p = .165). A final analysis indicated that for White/Non-Hispanic participants who were not successful on their initial attempt and made multiple attempts, the mean scaled score was higher for attempts made after participation in the intervention (n = 51, MS = 240.06, SD = 15.13) when compared to the mean scaled score of attempts made before participation (n = 12, MS = 225.50, SD = 14.71). The difference in the means of these scaled scores was statistically significant (t = -3.01, df = 61, p =.004).

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CHAPTER 1

INTRODUCTION

Background and Setting

The results of standardized teacher certification testing are used to measure content knowledge. As early as 2007 researchers such as Goldhaber noted that these types of test were being accepted by policymakers as the gatekeepers for teacher certification, despite findings that have not supported the practice. Earlier literature on the connection between teacher quality and effectiveness and certification testing reports mixed results and small correlations between the two, while also pointing out that these tests keep a greater number of teacher candidates who identify as belonging to ethnic minority groups out of the classroom (Angrist & Guryan, 2006; Goodman, Arbona, & de Rameriz, 2008). More recent research indicates that the process of teacher preparation and certification continues to be a barrier to increasing the diversity of educators (Ahmad & Boser, 2014; Carver-Thomas, 2018).

If the curriculum of the teacher preparation coursework does not adequately address what is tested on the certification exam, the consequences are substantial, for both the teacher candidate and the educator preparation program. The results of initial certification exams are used to grant teacher licenses and, in some states, are directly tied to the accreditation of the educator program that prepared the teacher candidate (Goldhaber, Liddle, & Theobald, 2012). The teacher candidate faces the cost and time of re-examination to pass the exam as well as the possibility of exceeding limits set on the number of attempts to pass. The educator preparation program could lose their ability to recommend teacher candidates to sit for certification exams if the number of successful exams attempts is not met.

Given that successfully passing (or not passing) certification examinations reflects most directly on the recommending educator preparation program (EPP), those who work within the education program need to ensure students possess not only adequate pedagogy, but also content knowledge that will be tested as part of the initial certification exam. Due to the fact that students often receive their science content from science departments who, as general rule, do not teach the content within the context of teaching, teacher educators would be better served to align the content with pedagogy within science methods courses. A goal of this study is to determine, if formal science training and the acquisition of PCK are taken together, will this combination best prepare preservice teachers to successfully pass their science certification exams?

Standardized tests are frequently called high stakes tests because of the importance of the score not only for the student, but also for their teachers, their school district and the teacher preparation programs that trained each teacher. Researchers as early as Cochran-Smith in 2004 and recently as Phelps, 2017 found that policymakers at all levels increasingly look for quantitative data to drive their decisions regarding aspects of education legislation and standardized testing provides an inexpensive, easily measured outcome that works well with statistical analysis. This preference for quantitative data has elevated the importance of standardized testing outcomes to its present level. As a matter of course, research analysis of the data generated by standardized testing is particularly impactful as it serves to increase high stakes testing for everyone involved in education, including those who educate teachers.

Problem Statement

Science content knowledge, in particular, has long presented a problem for elementary preservice teachers. The teaching of science in elementary grades first rose to prominence following the launch of Sputnik in 1957 (Tobin, 2002). In the decades that followed, research indicated that concepts from life, physical and earth and space science were particularly difficult for preservice elementary teachers to master (Blosser & Howe, 1970; Crawley & Arditzoglou, 1988; Schoon & Boone, 1989; Wenner, 1993; Ginns & Watters, 1995; Harlen & Holroyd, 1997; Parker & Heywood, 2000; Rice, 2005; Trumper, 1997). Accordingly, educational researchers sought to address the problem with learning science content by investigating what motivates students to learn science and by identifying instructional methods that promote understanding. This being said, more recent findings indicate that gaps in science content knowledge continue to persist across all the areas of science (Anggoro, 2017; Koc & Yager, 2016; Papadouris, Hadjigeorgiou, & Constantino, 2014; Potvin & Cyr, 2017; Stein, Larrabee & Barman, 2008; Trundle, Atwood, & Christopher, 2007).

Alongside the continued difficulties in learning science content, changes to certification exam requirements continue to add pressure to ensure preservice teachers have a robust understanding of science content knowledge. Policy changes in various states have significantly altered the content of exams, increased the cut scores required to pass, and set limitations imposed on the number of times teacher candidates can retest. These policy changes have helped to increase the stakes for teacher certification assessment to the level they are at today (Rojas, 2018; Shuls, 2018; Texas Administrative Code, §21.048). Each time preservice teachers register for an exam, there is a financial cost incurred that further adds to the desire to pass the certification exam in one attempt. The financial cost of making repeated attempts to pass these exams can present a barrier to some preservice teachers (Turner et al., 2017). Given the landscape of initial teacher certification testing, ensuring that preservice elementary teachers can demonstrate competency in science content knowledge remains a pressing issue for teacher educators.

Purpose of the Study

The purpose of this study was to determine the effect of a physical science intervention on the science domain score for the TExES Core Subjects EC-6, Science (804) exam. Currently, in Texas, the score report for the early childhood through sixth grade initial certification exam is disaggregated into subject tests which are further categorized into competencies. For the science subject test, there are eighteen competencies representing the three basic areas of science content knowledge: physical science, life science, and earth/space science that are assessed. The reported exam score presents a wealth of information about science content knowledge of test takers. This data, as was done in this research, can be analyzed as part of an educator preparation program's effort to evaluate the efficacy of their curriculum and improve their program and the quality of the teachers they train (Feuer, Floden, Chudowsky, & Ahn, 2013).

The data used to determine what preservice elementary teachers know about science as well as the effectiveness of changes made to coursework often comes from the use of pre- and post- tests administered during the course of a science content or science methods course. Some science content and methods courses have been modified with the aim of improving motivation and attitudes toward science teaching and learning and to address gaps in science content and pedagogical content knowledge based on the analysis of pre- and post- testing scores (Cervato & Kerton, 2017; Forbes, Sabel, & Zangori, 2015; Hrepic, Adams, Zeller, Taggart, & Young, 2005, Menon & Sadler, 2016; Santu, Maerten-Rivera, Bovis, & Orend, 2014; Verdugo, Solaz-Portolés, Sanjose, 2016). Though this method as has been found useful at an individual course level, this study, in contrast, focused on the program level by analyzing the certification exam data reported by the state certification agency. Specifically, the information provided by the testing agency of the science content assessed by the exam alongside the statistical analysis of test score reports was used to gain insight into the efficacy of a physical science intervention delivered as part of a science teaching methods course to improve science content learning. This approach to evaluating preservice teacher content knowledge is somewhat similar to the use of standardized testing data to evaluate teacher quality although it is focused on the content included in elementary science standards (Goldhaber, 2007; Goodman, Arbona, & de Ramirez, 2008; Hill, Umland, Litke, & Kapitula, 2012)

While the findings from university-developed assessments are useful in determining the efficacy of the coursework the student has completed, whether or not teacher certification will be achieved is ultimately dependent upon the state education agency's assessment measures (Texas Education Code, 2019). Given this reality, the importance of information that could be gleaned from data analysis of assessments taken as a part of educator certification is clear. Detailed results from certification exams, where available, can provide valuable insight for assessing the effectiveness of science content coursework and science teaching methods courses.

Theoretical Framework

In 1986, Shulman found that an effective teacher needed to possess three forms of knowledge to teach their students: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge (p. 9). The following year (1987) he went on to expand this list of three into a list of seven forms of knowledge that an effective teacher must possess to be successful: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of how the educational process works, and the knowledge of the purposes of education (p. 8). The three bases of content knowledge lay the foundation for this study and guide its examination of science content knowledge of preservice elementary teachers. The focus of this study will be on the intersection of content and pedagogical knowledge provided during a science methods course, as evidenced by the reported scores on the state certification exam.

Subject Matter Content Knowledge

In 1985, Leinhardt and Smith discussed content knowledge in their research on mathematics teaching and described content knowledge as “domain specific information necessary for the content presentation.” (p248). Shulman (1986) specified that subject matter content knowledge (SMK) included both an understanding of how a particular subject is organized as well as the rules that include or exclude content from the subject. Ball and McDiarmid later (1989) described subject matter content knowledge as including both “substantive knowledge of the subject” and “knowledge about the subject” (p. 8).   According to Zeidler (2002) SMK encompasses the quantity, quality, organization, conceptualizations, and constructs. More recent literature refers to this type of knowledge as academic content knowledge and defines it as “…the general factual knowledge that a teacher possesses about a specific topic” (Gess-Newsome et al., 2019).

In science specifically, SMK requires that there is an understanding of both the nature of science as well as scientific concepts themselves. This becomes particularly challenging as, according to Kuhn (1962) science is often characterized by practices of inquiry that are carried out to develop and expand the body of knowledge. He went on to describe science as something that is practiced through questioning, investigation, and experimentation, and that the understanding of phenomena evolves, sometimes resulting in significant changes. Kuhn (1962) further described the tenable nature of scientific knowledge as paradigm shifts in his seminal book, *The Structure of Scientific Revolutions*, and related it to solving puzzles. There are rules for solving puzzles to be followed when scientists go about the work of science which Kuhn termed “normal science”. Science knowledge includes methods of practice as well as the models, theories, and laws that constitute the body of scientific knowledge. Summed up by the the Next Generation Science Standards, “…science is both a set of practices and the historical accumulation of knowledge.” (2013, appendix h).

Pedagogical Content Knowledge

Shulman (1986) described pedagogical content knowledge (PCK) as encompassing “…the ways of representing and formulating the subject that make it comprehensible to others "(p.9). Accordingly, Shulman describes teachers with adequate PCK as knowing the best ways to teach particular concepts. Further, teachers with well-developed PCK not only know the content of what is taught but also which teaching methods work best to deliver the content to their students. Nilsson, in 2008, added that PCK makes content accessible to the learners as it includes knowledge of the requisite SMK combined with knowledge of a learner's strengths and weaknesses, knowledge of the curriculum to be learned, and the knowledge of a variety of instructional strategies.

In efforts to characterize PCK, researchers such as Loughran, Mulhall and Berry have suggested that there are two important components that PCK is comprised of: content representation and professional and pedagogical experience repertoire. This characterization of PCK illustrates the interconnected nature of PCK and SMK. Loughran, Mulhall, and Berry go on to state, "The foundation of (science) PCK is thought to be the amalgam of a teacher's pedagogy and understanding of (science) content…" (Loughran, Mulhall, & Berry, 2004, p. 371). Thus, the importance of content knowledge in the development of the teacher's PCK is highlighted when elementary preservice teachers deliver science instruction without it. Literature describes elementary lessons that cover density, energy transformations, and mechanisms of heredity taught with the focus of instruction shifted to the activities and away from the concepts (Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2013). Without adequate content knowledge on the part of the teacher, the activities included in the lesson, which are designed to support the content, can take precedence over the science content. That is to say, the teacher knows what to do with their students in a science lesson, but may not truly understand why they are doing it or understand the underlying science concept they are trying to teach. Both SMK and PCK enable to the teacher to navigate the connections across science concepts and make sense of all parts of a science lesson (Newton & Newton, 2001; Zeidler, 2002). However, a gap in scientific conceptual understanding reduces the preservice teacher's ability to evaluate the lesson material in a meaningful way or to make changes to the lesson that might allow their students to better learn the concept being addressed (Davis, 2006).

Research Questions

The research questions for this study were formed with the aim of determining what can be learned about the science content knowledge of preservice elementary teachers using the reported scores from the TExES Core Subjects EC-6, Science (804) exam. At the university where this study was conducted, elementary education students are required to take science courses within the science departments. The participants of this study would had competed at least 12 hours of science coursework and a conceptual physics course taught by College of Science faculty prior to enrollment in the science methods course. The science methods course included an intervention to determine and then address gaps in physical science content knowledge. Some attempts to pass the TExES Core Subjects EC-6, Science (804) exam were made before participation in the intervention (pre-intervention) while other attempts were made during or after participation (post-intervention). Although this study is not an intervention study in a strict sense, the term intervention refers to the combined activities that were incorporated into the science methods course with the purpose of providing physical science content instruction in the context of teaching. The data that is made available for analysis from the enrollment in the science methods course and the score reports determined the scope of the research. The data from course enrollment records provided data that allowed the time of the test in regard to the completion of the intervention as well as the self-reported ethnicity of the participant.

The intervention featured in this study targeted physical science concepts through demonstration lessons delivered by the faculty of the science methods course, and the process cycle of microteaching, feedback, and reflection on the part of the preservice elementary teachers (Long, Harrell, Subramaniam, & Pope, 2019). The three demonstrations lessons were designed to address Competency 8 of the science domain of the elementary certification exam that includes the topic related to the physical and chemical properties of matter. The demonstration lessons followed the 5E lesson plan model. The first lesson targeted the concept of buoyant force and included activities to aid in the understanding of floating, sinking, and water displacement. The second lesson targeted the concept of density and provided explanations and practice in calculating density paid specific attention to misconceptions related to the concept including weight, mass, and size (Harrell & Subramaniam, 2014). The third lesson addressed dissolving and the role of temperature in the dissolving process as well as solubility (Harrell & Subramaniam, 2015). The duration of the 3 demonstration lessons was approximately 12 hours of class time and included many hands-on activities and opportunities for both formative assessment and reflection (Long, Harrell, Subramaniam, & Pope, 2019). These three lessons can be found in Appendices B through D.

Each preservice elementary teacher enrolled in the course was also assigned a microteaching project that consisted of a physical science standard that they would design and deliver through the use of the 5E (engagement, exploration, explanation, elaboration, and evaluation) lesson plan model (Bybee & Landas, 1990). At the start of the course, guidance on 5E structure was delivered to aid in construction of the lesson plan and ensure that each component of the model was present. The physical science standards assigned were from the fourth, fifth, and sixth grade levels of the Texas Essential Knowledge and Skills Standards (TEKS) for science (Texas Education Agency, n.d.). Each preservice teacher in this study experienced up to 24 different lessons delivering instruction on physical science topics found in chemistry, physics, and Earth/space science that are assessed by the certification exam, the TExES Core Subjects EC-6, Science (804).

The enrollment data made available from the science methods course and from the score reports for each attempt to pass the certification exam were used to develop the following research questions for this study:

> Research Question 1: Among all participants who made repeat test attempts, is there a statistically significant difference in the TExES Competency 8 and the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention?
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> Research Question 2: After participation in a physical science intervention, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for repeat test takers who self-identify as Hispanic/Latino and those who self-identify as White/Non-Hispanic for participants?
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> Research Question 3: Among White/Non-Hispanic participants who made repeat test attempts, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention?

Assumptions

Several assumptions formed the basis for this research study. The first assumption is that the sample that was used for the study was representative of the larger population of students who are attempting to obtain elementary teacher certification. The sample for the study was from a large public university in Texas. Statistics compiled by the U.S. Department of Education show that as of 2017 there were over 68,000 students enrolled in education training programs in Texas, the largest number of education students in any state and about 15% of the total number of education majors in the country (National Center for Education Statistics, 2018). Initial teacher certification in Texas requires the successful completion of a standardized testing measure developed and administered by a testing company that also develops and administers teacher testing programs in a majority of states. The university program in this study has an accreditation profile that is similar to other educator preparation programs. The program is currently accredited by its state agency for educator certification and the Council for the Accreditation of Educator Preparation (CAEP).

The second assumption is that standardized testing measures are and will continue to be an important tool used to measure the content knowledge of teacher candidates by certification granting agencies. Policymakers at all levels look for quantitative data that is easy and inexpensive to gather to drive their decisions regarding aspects of education legislation which is often based on testing with multiple choice responses because of the ease in analysis compared to more subjective types of assessment (Cochran-Smith, 2004). The majority of states require the successful completion of standardized tests that are designed to measure the science content knowledge of elementary preservice teachers as a part of the decision to grant teacher certification (National Center for Education Statistics, 2018). This assumption supports this study in that it provides the rationale for the use of a measurement tool that was not developed by the researcher conducting the analysis. Indeed, any knowledge of the questions on the TExES EC-6 Core Subjects, Subject Test (#804) used for analysis is provided by the testing agency and cannot be directly evaluated by the researchers. Matching the test questions to the competency which they are reported to assess is done by the test agency.

The final assumption is built upon the previous assumption. If it is accepted that standardized testing measures will continue to be used as the gatekeeper for teacher certification, then teacher educators may be prepared to help their own students successfully navigate certification exams if they have a sound understanding of the content and structure of the tests (Zigo & Moore, 2002). Analysis of preservice elementary teacher performance on tests that address science content can offer insight into areas of strength and weakness preservice teachers present when completing the science subject certification test even if it is impossible to conduct an analysis of the actual questions. In other words, despite the fact, or possibly because of the fact, that the testing instrument used to generate data for this study was not developed by the teacher educators within the educator preparation program itself, potentially, this data will be of greater value.

Definition of Terms

- *Competency:* Description of specific content knowledge or pedagogical content knowledge can be included on an exam (Texas Education Agency, 2018).

- *Subject matter content knowledge*: Refers to the "concepts, facts, and skills" associated with a particular subject (Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013, p. 1022).

- *Subject pedagogical content knowledge*: "A second kind of content knowledge is pedagogical knowledge that goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p. 9)

- *Standards: "Learning* standards are concise, written descriptions of what students are expected to know and be able to do at a specific stage of their education" (Common Core State Standards Initiative, 2019).

Summary

The reliance of teacher certification agencies on standardized testing as the preferred measure of teacher quality requires that educator preparation programs pay close attention to the content of the tests their preservice elementary teachers must pass. Careful analysis of the data collected as a part of the initial certification examination score report may provide valuable information about the teacher candidate's understanding of science concepts. For this study, the results reported by a testing agency on the certification exam TExES Core Subjects EC-6, Science (804) which assesses science content knowledge along with enrollment data for a science methods course was used to answer several research questions of interest to teacher educators. The questions that guided this research addressed specific competencies within the scope of the science subject test as well as the effectiveness of a science intervention on test scores.

CHAPTER 2

RELATED LITERATURE

Introduction

Policy makers in education most often require accountability for learning that is demonstrated at least in part by the ability of a student to pass a standards-based, multiple choice test. In response to this requirement, much of the recent research in teaching and teacher education has reported on whether or not the content knowledge of both in-service and preservice teachers is sufficient to successfully teach the standards that will be assessed (Cohran-Smith & Villegas, 2015). As a part of learning about knowledge of teachers, educational researchers have devoted much time to understanding how content is learned in hopes of addressing any gaps that exist during the teacher training process.

A large body of educational research demonstrates the interest by educational researchers in developing a clear understanding of what preservice teachers know regarding subject matter knowledge and pedagogical content knowledge as well as the processes involved in their learning. Studies designed to measure the subject content and pedagogical content knowledge of preservice teachers incorporate a variety of measurement tools, both quantitative and qualitative in design (Cervato & Keaton, 2017; Ginns & Watters, 1995; Harrell & Subramaniam, 2014; Kirst & Flood, 2017; Lee & Shea, 2016; Parker & Heywood, 2013; Rice, 2005; Stein, Larrabee, & Barman, 2008; Zembal-Saul, Blumenfeld & Kracik, 2000).

Certification granting agencies, on the other hand, focus on measuring what preservice teachers know when granting teacher certification using quantitative measures (Goldhaber, 2007). In the vast majority of states, what preservice teachers know about subjects and about teaching is measured using standardized tests. Despite any protests from those working inside teacher preparation programs and data that shows little, if any correlation, between certification examination results and success in the classroom, knowledge that is measured by means of standardized testing remains a readily accepted as a reliable indicator of the quality of the teacher candidate and the EPP the teacher completed (Angrist & Guryan, 2007; Buddin & Zamorra, 2009; Goodman, Arbona, & de Rameriz, 2008; Harrell, 2009). This reliance on standardized testing to measure the content knowledge of the teacher candidate dictates that teacher educators pay close attention to what is covered on the tests themselves.

The review of literature science knowledge of preservice elementary teachers begins with important events in recent history that contributed to the value that is now placed on science teaching in public schools and on the science content knowledge of the school teachers. Next, changes in the understanding of the role of subject content knowledge plays in the development of pedagogical content knowledge is discussed. Third, the identification of gaps in the teacher's science content knowledge and efforts undertaken by educator preparation programs to improve science instruction are discussed. Finally, recent trends in measuring science content knowledge of teachers are described.

Background

Science Teaching in Public Schools

The increased focus on the science content knowledge of teachers was strongly influenced by the same historical events that promoted the reliance of standardized testing measures on policymakers and educational stakeholders to measure all types of content knowledge. Bearing this in mind, the most appropriate place to begin is where many researchers begin their discussion on science education, the launch of Sputnik during the Cold War. As the Soviet Union launched the *Sputnik* satellite in 1957, Americans experienced what they perceived to be a loss of the technological race, or at the very least, a rise in their collective fear of falling behind the rest of the developed world (Tobin, 2012).

As *Sputnik* soared into space, shoring up science and technology education suddenly became much more important to people outside the school. Organizations and institutions that influenced educational policy paid increased attention to on how science was taught in the nation's schools. Educational researchers began focusing on science in the elementary classrooms, and early published findings from the1960s indicated that elementary teachers were not eager to teach science as they did not feel familiar with the concepts and did not feel competent in their ability to use the equipment required for science investigations (Victor, 1962). The teachers reported that they were much more comfortable focusing on the activity or process and the not the underlying scientific principles, a finding that would remain problematic for decades.

The problems associated with science teaching in public schools were framed as the result of two problems: science content knowledge deficiencies among teachers and poor content knowledge training in educator preparation programs (Cochran-Smith, 2004). These deficiencies were attributed to inadequate preparation by teacher education programs that did not address the content knowledge needs of prospective teacher candidates. Along with not ensuring that prospective teachers mastered the required content was the added issue of lower achievement standards required to enter the teaching profession compared to other professions (Blosser & Howe, 1970; Levine, 2006). So, while preservice teachers were being taught the methods of teaching, they were not receiving adequate training for exactly what concepts they should be teaching and their content knowledge remained inadequate for the task of teaching science (Levine, 2006).

Three decades after Sputnik focused attention on science in public schools, the publication of *A Nation at Risk* in 1983 by the National Commission on Excellence in Education served to remind the nation that science education was still lacking. A *Nation at Risk* pointed to the poor results of American students on the most popular standardized tests that were utilized at the time of its publication as evidence for deficiencies. The tests referenced by the report were the *Scholastic Aptitude Test* (SAT) and the College Board's achievement tests from advanced placement courses. The publication of this report marked an important moment for standardized testing because it was the first time standardized testing measures were presented to a broad audience as reliable indicators of the quality of education (Tobin, 2012). Importantly, testing data allowed people outside of the educational institutions to make determinations on the quality of the key components of education using achievement data without ever stepping into the classroom themselves.

The dismal test results of students in public schools were used to draw the conclusion by many policy makers and other stakeholders in education that teacher training programs were still not preparing their graduates to teach science properly. Research studies conducted at this time also revealed issues that continued to persist in teacher training as elementary teachers grappled with the feeling that they were not qualified to teach science and continued to approach science instruction with hesitancy (Crawley & Ardizoglou, 1988). The results of this hesitancy to teach science showed up in the primary school. As many as a quarter of elementary teacher respondents indicated that they that they did not spend any time teaching science in their classrooms (Tilnger, 1990). Throughout the 1990's research continued to document the difficulty teachers experienced with life, physical, and earth/space science concepts during their teacher preparation and after they began their own practice (Ginns & Waters, 1995; Harlen, & Holroyd, 1997; Lederman, 1999; Trumper, 1997).

Content Knowledge and Teacher Quality

Alongside the developments in the nation's awareness of science content difficulties at the primary school level among students and their teachers, the concept of standardized testing was in the process of evolving into a highly prized indicator of teacher quality and the quality of instruction. Just a few years after the publication of *A Nation at Risk* (1983) the National Board for Professional Teaching Standards (NBPTS) formed to design better standards for teacher certification in 1987 (National Board for Professional Teaching Standards, 2018). These standards were used by EPPs to design their programs and included on teacher certification exams used to measured content knowledge of the preservice teacher.

In 1991, the Department of Education published *America 2000: An Education Strategy* articulating the need for additional testing across schools and grades to inform on the quality of the instruction that students were receiving. Importantly*, America 2000* called for the development of tests to assess five core subjects taught in schools (U. S.

Department of Education, 1991, p13). This publication was significant in that it stressed the need for still more testing to improve public education and paved the way for the legislation that would promote standardized testing to the level of prominence it occupies today.

Next, the passage of the *No Child Left Behind Act* of 2001 (*NCLB*) placed unprecedented value on testing of students at all levels of education across several subjects. States wishing to continue to receive Title I funds would have to develop, administer, and report on accountability measures that included standardized testing. Directly addressing teacher quality, *NCLB* mandated that states ensure that highly qualified teachers were in every classroom where core subjects are taught (Birman, et al., 2007). Accordingly, states were required to develop high standards for certification. Certification requirements included testing to measure content and pedagogical knowledge as part of the process of becoming highly qualified. “Highly qualified” was the label used in the legislative text to denote teachers who held the state recognized teacher certification. The *Race to the Top* grant program followed in 2009 and tied large amounts of money to international testing measures through grants (Lohman, 2010).

Every Students Succeeds Act of 2015 (*ESSA*) replaced *NCLB* in and went into effect with the 2017-2018 school year. Although *ESSA* removed much of the oversight by the federal government on accountability measures, including the highly qualified mandate, the law maintains the requirement for states to set high standards for teacher certification (U.S. Department of Education, n.d.). Many states have retained the certification processes they developed under *NCLB* legislation thus ensuring the importance placed on standardized testing in evaluating teacher candidates for competency remains in place.

Subject Matter Content Knowledge in Teaching

In the wake of the crisis in education uncovered by a *Nation at Risk*, the attention in educational research turned to a closer examination of the need for teachers to possess more than training in instructional strategies and classroom management. Education researchers asserted that effective teaching required subject content knowledge that could not be gained by the teacher while practicing their craft but rather must be included as a part of teacher preparation before entering the classroom (Cochran-Smith, 2004; Shulman, 1986). A few years before Shulman published seminal works on the subject knowledge of teachers, Buchmann (1983) stated that, “strategic and logical acts of teaching” would only occur if teachers had adequate knowledge about their subject (p.8). Buchmann contrasted these acts of teaching with the actions taken in the classroom that we associate with the processes of schooling. Schooling encompasses the procedures of the teacher, the classroom, and the school that allow each to function within the education setting. The point to take from this distinction is that the activities of educating of students can take place separate from the learning of the student depending upon the knowledge of the teacher (Buchmann, 1983).

Importantly, adequate content knowledge permits the teacher to attend to the student’s thinking beyond merely correcting wrong answers. Buchmann succinctly states, “…no amount of reflection, observation, general information or understanding or personal experience overcomes the lack of knowledge…”(1983, p. 16). In the same way that working at a hospital and doing the things associated with hospitals does not make someone a doctor, working in a classroom doing things associated with schools does not make someone a teacher. Performing activities associated with learning science will not ensure that students learn science concepts unless the teacher is keenly aware of the concepts themselves.

Science Content Knowledge (SCK) and the Elementary Teacher

Specifically addressing science content knowledge (SCK), elementary educator preparation programs must ensure that preservice teachers have sufficient knowledge of science facts and an understanding of how science knowledge advances to allow their graduates to be able to move past schooling to educating their own students (Texas Education Code, 2019). The science standards that must be taught in the elementary grades cover a wide array of topics in life, physical, and earth/space science and are outlined as standards by a variety of accreditation agencies at the state and the national level. EPPs use the standards adopted by the accreditation agencies to develop their own science curriculums for their courses.

States' accreditation agencies vary in the resources they use to develop their own science content standards (National Research Council, 2012). The *Next Generation Science Standards (NGSS, 2013)* were developed nationally by several committees representing academia, engineering, and medicine, as their science standards and have been adopted by twenty states (Bendici, 2019; Bybee, 2014). The *NGSS* gives a detailed listing for content knowledge in science and outlines what students at each grade level should know about science and be able to do when studying science. The *NGSS* were developed using the *Framework for K-12 Science*

Education, a report published in 2012 by the National Research Council to update the goals for science education in the United States (National Research Council, 2012; Wysession, 2013). Another twenty-four states have developed their own standards using the *Framework for K-12 Science Education* (Bendici, 2019).

The National Science Teachers Association (NSTA) along with the Council for the Accreditation of Educator Preparation (CAEP) used the *NGSS* to develop their own standards for programs seeking to maintain CAEP accreditation. This study described in this paper was conducted at a university in Texas where the State Department of Education has developed the *Texas Essential Knowledge and Skills* which include the science standards for elementary grades (Texas A&M Web Archive, 2011). Science content standards for elementary preservice teachers include the physical science concepts of the properties of matter, chemical and physical change, energy transformations, motion, and waves. Life science content covers the structure and organization of organisms, processes in living things, ecosystems, heredity, and evolution. Earth and space concepts include content on space systems, earth surface systems, weather and climate and human impact on the earth's processes and systems (CAEP, 2018).

Science knowledge encompasses both a collection of facts as well as a way of approaching problems. Planning and carrying out investigations through inquiry learning is also an important facet of training elementary teachers and is assessed as part of certification exams. The scientific approach to problems that includes making observations, testing hypotheses, and drawing conclusions from experimentation are captured in the "Practices for K-12 Science Curriculum" in the *Framework* as well as

NSTA standards (Wysession, 2013). To ensure their programs present their curriculums in ways that align with national standards, EPPs must teach not only the facts but also the methods of inquiry that are utilized in science (Lee & Krapfl, 2002; Menon & Sadler, 2018, NSTA Board of Directors, 2000).

Science PCK and Science Teaching

Preservice teachers must have a well-developed understanding of science content to build their knowledge of how to teach science (Buchmann, 1983; Ball & McDiarmid, 1989; Loughran, Mulhall, & Berry, 2004; Zeigler, 2002). The knowledge of how to teach a subject or pedagogical content knowledge (PCK) is another of the three types of content knowledge required of teachers (Shulman, 1986). The relationship between SCK and PCK is an important one that cannot be overlooked by those who training elementary teachers to teach science (Parker & Heywood, 2000). PCK is the ability of the teacher to recognize troublesome misconceptions commonly associated with a topic and address them to guide the students' thinking. PCK is also the knowledge of how to learn a skill in a way that limits the frustrations of the learner and fosters curiosity of a topic. PCK enables teachers to respond to their students' needs as the learning process unfolds and make changes to lessons as needed. A teacher who has developed a large repertoire of PCK covering the topics in the subject is able to not only teach the content of the topic but also design learning experiences that make the difficult process of learning a little less challenging. As Shulman articulated so well, knowing about a topic and knowing how to teach that topic are truly two separate things both requiring expertise.

Gaps in SCK

Many studies have investigated the specific gaps in science content knowledge of preservice elementary teachers as part of an effort to improve teacher training programs. Results from studies show difficulties with science content to be widespread among preservice elementary teachers across all areas of science knowledge including physics and chemistry concepts (Anggoro, Widodo, & Suhandi, 2017; Ginns & Waters, 1995; Harrell & Subramaniam, 2014, 2015; Papadouris, Hadjigeorgiou, & Constantinou, 2014; Potvin & Cyr, 2017; Rice, 2005; Stein, Larrabee, & Barman, 2008; Trumper, 1997), life science (Crawley & Aditzoglou, 1988; Forbes, Sabel, & Zangori, 2015), and earth/space science (Koc & Yager, 2016; Parker & Heywood, 2000; Trundle, Atwood, & Christopher, 2006). Important factors that have been found to contribute to difficulties in learning science content include inadequate science content coursework and ineffective instruction in science content coursework that does not address negative perceptions of science or resistant misconceptions about science (Akerson, Morrison, & McDuffie, 2006; Kazempour, 2013; Trygstad, 2013; Velthius, Fisser, & Pieters, 2014).

Comparing preservice elementary teachers to preservice science teachers (those who will teach only science at the middle or high school level) helps to understand just how few science content courses preservice elementary teachers complete as a part of their training. The 2012 National Survey of Science and Mathematics Education results indicated that only 36% of kindergarten through fifth grade teachers had taken courses in all three of these areas of science while completing teacher training (Trygstad, p. 4). In one study, preservice elementary teachers completed five science courses while preservice science teachers completed at least four times as many science courses

(Kaya, 2013). Another study included preservice elementary teachers who completed only two science courses prior to their science teaching methods courses (Lee & Shea, 2016).

The science coursework these students do complete often does not adequately ameliorate student misconceptions about science (Akerson, Morrison, & McDuffie, 2005; Bergman & Morphew, 2015; Bleicher & Lindgren, 2005; Kazempour, 2013). Preservice teachers often report negative experiences with science courses and poor perceptions of science even after completing science content coursework and upon beginning science teaching methods courses. In light of this finding, many educational researchers have studied ways to teach science content more directly in methods courses and improve the motivation to learn science in both content courses and methods courses (Avery & Mayer, 2012; Lee & Krapfl, 2002; Palmer, 2004).

Misconceptions about science, also called alternative conceptions, have been shown to impact the ability of preservice elementary teachers to learn science concepts and maintain their understanding over time. Some alternative conceptions of science prove to be more detrimental to the development of preservice elementary teachers' understanding of science concepts. Alternative conceptions of science also prove very resistant to instruction. Mesci and Schwartz (2017) reported that alternative conceptions of the nature of science, including the concepts of scientific theories and scientific laws, were particularly difficult to change among preservice elementary teachers despite interventions designed to address them. Educational researchers would continue to investigate ways to teach science that would result in accurate and durable science content knowledge of preservice teachers.

Addressing the Gaps

Findings that indicated the existence of a persistent lack of science conceptual understanding highlighted the need for continued improvement in how science was approached in education preparation programs. Educational researchers hoping to improve science conceptual understanding among preservice elementary teachers began to draw upon the research on motivation to learn (Hidi & Renninger, 2006). Teacher educators began to incorporate the kinds of instructional practices that preservice teachers were taught to use in their own classrooms to present science content to the preservice teachers. These instructional practices, which were inquired-based and student-centered in nature, were found to contribute to learner interest and to increase the motivation of the student to learn science (Palmer, 2004). In literature, the practices that are associated with student-centered instruction or are inquiry-based are often referred to as course innovations and interventions.

Innovations for courses that teach science to preservice elementary teachers should address science content through inquiry-based learning opportunities, multiple experiences observing good teaching, and multiple experiences with practice teaching or microteaching both as a part of the course and in the elementary classroom (Ernst, 1994; Lee & Krapfl, 2002). Innovations and interventions that researchers have investigated include the incorporation of problem based learning, project based learning, novel experiences and hands-on activities, peer instruction, and reflection; all of which can also be described as inquiry-based learning practices and a part of the constructivist learning model (Palmer, 2004 & 2016; Penderson & McCurdy, 1992). Promising findings regarding science content knowledge, science pedagogical content knowledge, and motivation to learn science among preservice teachers who completed courses that included these innovations supported the continued study of innovative instructional practices in both science content and teaching methods courses.

Beyond Lectures: Innovations and Interventions

Inquiry-based instructional practices have been shown to improve the science content knowledge of the preservice teacher. Science course interventions were studied by Pedersen and McCurdy in 1992 with findings indicating that preservice teachers' attitudes towards science learning were positively affected by inquiry learning activities completed as part of a science teaching methods course. A decade later, Lee and Krapfl (2002) described improvements in attitudes towards science when new science content courses were designed for preservice elementary teachers using a "constructivist teaching-learning framework" that accommodates cooperative, problem-based, hands-on inquiry as the foundation of its curriculum (p. 252). Palmer (2003) reported on a course that combined science content and science teaching methods designed to identify sources of interest in learning science among preservice elementary teachers. Palmer, Dickson, and Archer (2016) further reported that the effectiveness of course innovations and attributed their findings to increased interest by the preservice teacher which contributes to greater attention to and learning of the content.

Additional evidence of positive effects on science learning and science teaching from course innovations has also been demonstrated by several studies conducted in the last two decades. In each of the areas of science instruction—physical, earth/space, and biological science, positive findings have been reported on interest in learning science, science content knowledge, and science pedagogical content knowledge. When data from a physical science content course that was modified to include cooperative learning, and peer instruction was analyzed, it showed gains in positive attitudes about science and increased familiarity with inquiry-based learning environments (Hrepic, et al., 2005). Courses that address earth and space concepts have also benefited from the inclusion of innovative practices. In 2017, Deehan, Danaia, and McKinnon reported on improvements in the science content knowledge of students who completed two successive astronomy courses that included constructivist-based teaching innovations as well as mentoring, microteaching, and an emphasis on the real-world relevance of the science content.

Increases in conceptual understanding have been reported in the literature as well. In life science, plant processes were taught using an inquiry based intervention as part of a science teaching methods course, a practice which yielded gains in conceptual understanding among students (Thompson, Lotter, Fann, & Taylor, 2016). Forbes, Sabel, and Zangori (2013) reported increases in conceptual understanding of several life science topics including life processes, inheritance, and ecology as measured by pre- and post- tests by students completing a course that incorporated formative assessment in the design. Menon and Sadler (2016) reported positive findings on conceptual understanding after completing a physical science content course taught by instructors in the physics department that covered electromagnetism, uniform motion, and forces taught using inquiry based instructional practices.

Reflective practices are another valuable way to innovate courses to improve the learning of science for prospective teachers that are also student-centered. Research lessons, or lesson study, feature specific components: observation by other teachers and/or recording of the lesson delivery in some way, followed by reflection through oral discussion or written notes (Lewis & Tsuchida, 1999). Findings from this study indicated that reflective practices are useful in promoting science content knowledge. Zembal-Saul, Blumenfeld, and Krajcik (2000) found that guided cycles of planning, teaching, and reflection also resulted in improved science content accuracy in the delivery of science lessons by preservice elementary teachers. Specifically, Zembal-Saul et al., reported that the preservice teachers in their study exhibited, “content representations that included increased emphasis on organizing instruction around central ideas” (p. 334). This finding is important as it suggests that these students were developing a deeper understanding of science content evidenced by improved ability to evaluate the organization of science topics as they participated in the repeated cycle of teaching and reflection on the same lesson.

Later on, Marble (2007) reported positive outcomes on the presentation of the science content as preservice teachers progressed through iterative cycles of teaching and reteaching the same lesson. In this study, preservice teachers enrolled in science teaching methods courses taught the same lesson multiple times to different students and followed up their teaching with reflective activities (Long, Harrell, Subramaniam, & Pope, 2019). Reflective practices have also been shown to helpful in the correction of alternative conceptions among preservice elementary teachers (Akerson, Pongsanon, Rogers, Carter, & Galindo, 2015; Hawkins & Rogers, 2016).

Expanding the Catalog of Innovations

Other course modifications, including emphasis on formative assessment, informal learning environments, and development of argumentation skills while learning science content, have been shown to be beneficial for science learning among preservice elementary teachers. Kelly (2000) pointed out the importance of opportunities for learning that could be provided to preservice elementary teachers outside the traditional classroom. The inclusion of informal science learning environments such as science museum, zoos, aquariums, parks, and other locations beyond the classroom extends the opportunities for learning and encourages reflection. Findings from the analysis of interviews on preservice elementary teachers published by Avraamidou in 2015 reinforce Kelly's argument. Avraamidou reported on the experiences of preservice elementary teachers who, as part of a science teaching methods course, visited three different informal science learning environments. The visits were shown to help the preservice teachers develop their own ideas about science teaching and learning as well as their ability to find personal relevance in science concepts.

The benefit to science content knowledge from learning the process of scientific argumentation, a process that includes providing evidence to support scientific claims and purposeful listening to and contemplation of differing viewpoints, has also been demonstrated in the literature. Koenig, Schen, and Boa (2012) and Faize, Husain, and Nisar (2018) both reported similar positive findings regarding preservice elementary teachers' understanding of the nature of science when explicit instruction on content was paired with the development of scientific reasoning skills.

Student interest and learning of science increases when methods for instruction beyond the traditional lecture are incorporated into the training for preservice elementary teachers. Bearing this in mind, the course innovation used for this study was an intervention targeting physical science misconceptions during the science methods course. The intervention consisted of three demonstration lessons targeting buoyancy and dissolving that were presented to the preservice teachers by the faculty of the science methods course. The intervention also involved microteaching lessons of physical science concepts aimed at increasing the preservice elementary teacher's pedagogical content knowledge of physical science by the preservice elementary teachers. The participants were assigned two topics covered in physical science and instructed to prepare lessons for their topics. The topics for microteaching included those discussed earlier that prove to be difficult for preservice science teachers to master: "buoyancy, dissolving, average speed, energy transformations, and electrical circuits" (Long, Harrell, Subramaniam, & Pope, 2019, p22).

Measuring SCK of Elementary Preservice Teachers

Many of the studies cited for here reporting on improvements in SCK and PCK relied on measures that were developed by educational researchers and those who develop and deliver the curriculum used in teacher preparation courses such as pre- and post- content exams, interviews, and surveys (Bergman & Morphew, 2015; Bilgin, Karakuyu, & Ay, 2015; Kirst & Flood, 2017; Korb, Sirola, & Climack, 2005; Lee & Krapfl, 2002; Papadouris, Hadjigeorgiou, & Constantinou, 2014; Parker & Heywood, 2013) . It is important to keep in mind that the measures used by accreditation entities are the final word in determining whether or not teacher candidates have acquired the requisite content knowledge to obtain certification and are not the same measures as those used by the teacher preparation programs. These testing measures are most often developed and administered by testing companies that are not associated with the educational preparation program.

The department of education in individual states generally relies on tests that are developed and administered by testing companies to determine if teacher candidates meet their required threshold for SCK and science PCK. Initial teacher certification is currently dominated by two testing companies: Educational Testing System (ETS) and Pearson (Educational Testing Service, 2019; National Center for Education Statistics, 2018). ETS develops and administers the teacher certification exams used in a majority of states, the PRAXIS I and PRAXIS II exams, to candidates recommended by educator preparation programs. For elementary teacher candidates, the first of these two tests assess pedagogical skills and the second covers content. The content test is often broken down into subtests that cover specific disciplines of study. All of the testing components of the PRAXIS I and II are comprised solely of selected-response questions.

Pearson also administers teacher certification assessment through their National Evaluation Series of tests in over 20 states. These states have contracted with Pearson to develop custom tests aligned to the state's specific standards (Pearson, 2019). Pearson began administering the initial teacher certification exams for the state of Texas through the Texas Educator Examination Program in 2018. Both ETS and Pearson generally conduct their assessments through the digital delivery.

Achieving a passing score on the certification exams is paramount for teacher candidates as well as the educator preparation program that recommends them for testing. As mentioned earlier, it does not matter than many studies point to the irrelevance of these scores in predicting teacher quality as state education agencies overwhelming rely on them to eliminate teacher candidates (Angrist & Guryan, 2006; Buddin & Zamarro, 2009; Goodman, Arbona, & de Rameriz, 2008; Kane, Rockoff, & Staiger, 2008). Increases to passing scores as well as extensive changes to the content of certification exams have led to disastrous outcomes in terms of the number of students recommended for teacher certification in several states including Michigan, Missouri, Indiana, Illinois, and Florida (Shuls, 2018).

In Texas, where this study was conducted, the pressure to achieve a passing score is made worse by recently enacted limits on the number of times teacher candidates can re-test should they not pass all parts of the exam the first time they test as well as mandatory accountability reporting required by the recommending educator preparation program (Texas Administrative Code, 2016). A solid understanding of the assessment tool itself is therefore an important part of preparing preservice elementary teachers to demonstrate their competence on all required measures for certification. So important is familiarity with the assessment tool used for certification that some teacher educators have reported taking certification exam themselves (Zigo & Moore, 2002).

Summary

Ensuring teacher candidates have mastered the science content that will be tested as a part of the certification examination process and also are competent to teach using the types of inquiry based-teaching practices adopted by accreditation agencies are two of the most important tasks of teacher educators. This literature review has discussed the important concepts that shape the environment in which these tasks must be completed beginning with the value placed on science knowledge by policy makers and stakeholders in education and deficiencies in science teaching in public schools illuminated by standardized testing measures. Next, the subject matter content knowledge needed to teach science confidently and accurately was described along with efforts to identify science content knowledge gaps. Finally, efforts to address science content knowledge gaps and the measures used to determine the success of these efforts was discussed. The measure of the success or failure of these efforts will largely be determined by standardized testing measures over which the EPP has little control, a fact that highlights the importance of analysis of any data made available by certification testing agencies.

CHAPTER 3

METHODOLOGY

Introduction

The review of literature relevant to initial teacher certification provides the basis for ongoing efforts to find ways to deepen the science content knowledge of preservice elementary teachers. The purpose of this study is aligned with this goal of other teacher educators and sought to determine the impact of a physical science intervention during a science methods course on the science domain score for the TExES EC-6 Core Subjects, Science (804) exam scaled score. IRB approval was obtained in to gather enrollment data for the science methods course as well as to examine the test results for the participants.

This chapter details the methodology used for this study beginning with the purpose of the study and the research questions addressed. The methods section then describes the aspects of the study including a description of the participants, data sources and collection, and data analysis. Next, the study assumptions are briefly restated followed by a discussion of limitations and delimitations. The chapter closes with a discussion of the ethical considerations that must be made in the implementation of this research.

Purpose of the Study

The purpose of this study was to determine the impact of a physical science intervention during a science methods course on the scaled score for the TExES Core Subjects EC-6, Science (804) exam. With this purpose in mind, the study was conducted using data provided by a state testing agency to better understand the science content knowledge of preservice elementary teachers before and after participation in a physical science intervention. Studies discussed in the literature review provided support for the purpose of this study as well as the study design (Kane, Rockoff, Staiger, 2008; Lee & Shea, 2016; Norris, 2013; Potvin & Cyr, 2017; Santu, Marten-Rivera, Bovis, Orend, 2014; Shuls, 2018).

Literature reports on the use of test scores from certification tests from state testing agencies to investigate the relationship between certification passing rates and scores and teacher effectiveness (Goldhaber, 2007). Teacher effectiveness is often described using the term “quality” and some studies examined in the literature review paired certification data with measures of student achievement that occurred after the preservice teacher entered their own classroom (Hanushek, Kain, O’Brien, & Rivkin, 2005; Angrist & Guryan, 2006; Goldhaber,2007; Goodman, Arbona, Ramieriz, 2008). In a departure from the aims of these types of studies, this research fills a gap in the literature by focusing on how certification exam data can generate useful statistics to better understand the effectiveness of what goes on in the science methods course before the preservice teacher leaves the educator preparation program.

PS Intervention

Literature discussed in the previous chapter presents evidence of the difficulty preservice elementary teachers experience across all areas of science (Anggoro, Widodo, & Suhandi, 2017; Ginns & Waters, 1995; Harrell & Subramaniam, 2014, 2015; Koc & Yager, 2016; Papadouris, Hadjigeorgiou, & Constantinou, 2014; Parker & Heywood, 2000; Potvin & Cyr, 2017; Rice, 2005; Stein, Larrabee, & Barman, 2008; Trumper, 1997; Rice, 2005; Trundle, Atwood, & Christopher, 2007). Included among these references is research that looks specifically at physical science topics. Although this study is not an intervention study in a strict sense, the term intervention refers to the combined activities that were incorporated into the science methods course with the purpose of providing physical science content instruction in the context of teaching. The demonstration lessons that were featured in this intervention were influenced by the difficulty experienced by preservice elementary teachers when responding to questions from Competency 8 of the science domain of the certification test. An examination of the number of correct responses on the exam score report showed that targeting this competency which covers the chemical and physical properties of matter was warranted given the lower percent correct score correct for these questions.

Te three demonstration lessons presented to the participants in the science methods course by the course faculty provided instruction on buoyancy, dissolving, and density. The first lesson addressed the concept of buoyant force and included activities to aid in the understanding of floating, sinking, and water displacement. The next lesson covered the concept of density and provided explanations and practice in calculating density and explicitly addressed misconceptions related to the concept including weight, mass, and size. The third lesson addressed dissolving and solubility. The combined duration of the 3 demonstration lessons was approximately 12 hours of class time and included many hands-on activities and opportunities for both formative assessment and reflection (Long, Harrell, Subramaniam, & Pope, 2019).

Nature of the Study

This study is quantitative in nature and involved the collecting, recording, and analysis of initial certification examination data reported to the recommending teacher education program. Data was also collected from the enrollment records for the educator preparation program specific to when the science methods course was taken. This study does not include the manipulation of any variables or the random assignment to groups of the study participants and is non-experimental in nature (Gay, Mills, & Airasian, 2006). Non-experimental research is required when the manipulation of the independent variable and/or random assignment is not appropriate as is the case for this study (Price, Jhangiani, Chiang, Leighton, & Cuttler, 2017). While causal relationships are more difficult to establish using non-experimental research designs, there are still valuable conclusions that can be obtained from the findings given the constraints of research conducted in educational settings.

Research Questions

The research questions for this study were developed considering the constraints on the data that was available for collection. These questions are stated below.

> Research Question 1: Among all participants who made repeat test attempts, is there a statistically significant difference in the TExES Competency 8 and the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention?

> Research Question 2: After participation in a physical science intervention, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for repeat test takers who self-identify as Hispanic/Latino and those who self-identify as White/Non-Hispanic for participants?

> Research Question 3: Among White/Non-Hispanic participants who made repeat test attempts, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention?

Methods

Study Participants

Participants in this study were enrolled in the elementary education program at a large public university with a total enrollment exceeding 31,000 students. The program is accredited by the Texas Education Agency (TEA) and by the Council for the Accreditation of Educator Programs (CAEP). The participants have taken the early childhood through sixth grade initial certification exam, TExES Core Subjects EC-6, Science (804), during their enrollment in the science teaching methods course or following the completion of the course, which is the instrument used for this study. Participants include traditional college students who entered the program immediately following high school graduation as well as non-traditional, returning students who are older than students who enter post-secondary institution immediately following high school graduation. All participants completed a minimum of twelve hours of science coursework as part of the degree and took a conceptual physics course taught by College of Science faculty (Long, Harrell, Subramaniam, & Pope, 2019).

Participants in this study provided their ethnic identity which was used for some of the analyses in this study. The approach taken to report on the related findings and subsequent discussion was informed by guidelines provided by the American Psychological Association's publication *Race and Ethnicity Guidelines in Psychology: Promoting Responsiveness and Equity* (2019). The self-reported ethnicities used for this study included African American, Asian, Hispanic/Latino, Two or more races, and White/Non-Hispanic. At the time this study was conducted, the university reported that about half of their students (48%) identify as White/Non-Hispanic, about one quarter

(22%) identify as Hispanic/Latino, and 14% identify as African American. Of the 473 participants in the study, 65% self-identified as White/Non-Hispanic, 23% self-identified as Hispanic/Latino, 7% self-identified as African American, 3% self-identified as Asian, and 2% self-identified as Two or More Races.

Data Sources and Instrument

Each time a teacher candidate completes the science subject test of the initial certification exam a score report is generated by the testing agency. Some participants in this study completed the TExES Core Subjects EC-6, Science (804) exam multiple times with each score report generated by a test attempt being used as a case for this study. A total of 535 score reports from the Texas Education Agency's database were entered into a data file for candidates enrolled in the science methods course from August 2015 to May 2018. The score report obtained from the testing agency provided the date of test attempt, the science subject test score, the number of questions for each competency presented on the test, and the raw score for correct responses for each competency. Enrollment data from the program's science methods course provided the semester of enrollment in the course as well as the self-reported ethnicity of each participant.

The science subject test of the TExES Core Subjects EC-6, Science (804) exam was the instrument used to generate the data for analysis in this study. This test is composed of 45 questions representing eleven standards with 18 competencies based on science standards adopted by the state education agency for elementary teachers (Texas Board for Educator Certification, 2018). The number of questions that are categorized for each competency and the number of correct responses to those questions are provided on the score report and were recorded in the data file. The number of questions for each competency varied from 1 to 4.

The descriptions of each competency provided by the testing company was used to develop four categories of science content—nature of science (NOS), physical science (PS), life science (LS), and earth/space science (ES). Competencies 1-6 contain questions relating to the nature of science content and were not recorded for this study. The NOS competencies comprise 15 of the 45 science questions while the three areas of PS, LS, and ES include 10 questions each. The scaled score for the exam and the raw score for the PS area of the test were used for this study. In addition, the number of questions from each competency within the area of PS as well as the number of correct responses were also used for analyses. A brief description of each competency used for this study is given in Table 1 and a detailed description of each of the 18 competencies tested on the TExES Core Subjects EC-6, Science (804) exam is provided in Appendix A.

Table 1

TExES EC-6 Core Subjects, Science Test (804) PS Competency Descriptions

Competency Number	Overarching Concept
7	Forces, motion
8	Physical and chemical properties
9	Energy and interaction
10	Energy transformation/ conservation

Note. Total number of questions for each competency varied from 1-4 for a total of 10 PS questions.

Data Collection

The scoring and date of each test attempt was collected by downloading score reports from the certification agency test reporting database. The semester of enrollment in the science methods course as well as the self-reported ethnicity of the candidate was collected from enrollment data from the science methods course. The science methods course enrollment data and score reports for each attempt by participant was then used to create a Statistical Package for Social Sciences, SPSS, (Version 26) data file for analysis.

Data Analysis

Scores reports used were grouped for comparison based on when the exam attempt in regards to participation in the physical science intervention that was included in the science methods course, the self-reported ethnicity of the participant, and whether or not the participant completed multiple attempts to pass the exam. The independent variables for this study were the timing of the test attempt compared to the participation in the science intervention and the self-reported ethnicity of the participant. The self-reported ethnicities used by TEA were recorded for this study. These self-reported ethnicities include African American, Asian, Hispanic/Latino, Two or More Races, and White/Non-Hispanic. Participants who completed testing prior to enrollment in the science methods course were coded as pre-intervention while all others were coded as post-intervention.

The dependent variables included the scaled score for the TExES Core Subjects EC-6, Science (804) exam which ranges from 100 to 300 and a calculated percent correct score for each of the individual PS competencies. To calculate the percent correct score, the number of questions as well as the number of correct responses was recorded for each competency. The percent correct responses were used for analyses because the number of questions for each competency varied from one to four for each attempt. Independent samples *t*-testing was used to compare the means of the groups in the study. The level of significance (α) was set at 0.05. If the p-value calculated for each comparison was less than alpha ($p < 0.05$), the null hypothesis was rejected, indicating no statistical significance between the means of the groups. The data used for the analyses required that the results reported are for two-tailed tests of significance.

Analysis of the data was conducted using independent samples t-test modeling and the assumptions were considered prior to running each analysis. The dependent variable must be continuous; this assumption was met using the TExES Core Subjects EC-6, Science (804) score as one of the dependent variables. The second independent variable, the calculated percent correct responses score for the competencies was also continuous. Because the number of questions for each competency varies from one four for each exam, the percent correct responses for each score report must be calculated. This was done by recording the number of questions for each competency as well as the number of correct responses to these questions. The percent correct for each competency was then calculated and recorded using these two numbers.

The assumption of independence of observations was met as the data used for these analyses represents a distinct, separate attempt on the TExES Core Subjects EC-6, Science (804) exam. The assumption of homogeneity of the variance was tested using Levene's test for equality of variances for each analysis conducted. Statistical results were reported when equal variables were assumed. The assumption of normality was tested using a quartile-quartile (Q-Q) plot to examine the distribution of the scores on EC-6 TExES Science Subject Test (804).

Ethical Considerations

This study did not require direct interaction with the study participants or manipulation of variables and was limited to a review of data collected by the university and the testing agency's database. The data was coded for analysis and no personally identifying information was used for descriptions in the study or reported in any of the results. Score reports were downloaded from a secure database using the university's protected network. Of paramount concern is the safeguarding of the participants' records and all score reports and course information will remain the property of the university. IRB approval was applied for and granted for this study. The number assigned to this study is IRB-19-531.

Assumptions

There are three assumptions upon which this study is based. The first is that the sample chosen for this study is representative of the larger population of preservice elementary teachers. This study was conducted at a large public university in a state that has similar requirements for teacher certification to many other states in the country. The second assumption is that the testing measure used in this study, a science subject test from an initial teacher certification examination, is a valuable tool in determining the content knowledge of an elementary teacher candidate. The use of standardized tests as the deciding factor for certification of teacher candidate supports this assumption. The final assumption is that elementary teacher educators can use the data from certification testing to identify and address areas of science content knowledge weakness. The organization of the score report paired with the detailed descriptions from the testing agency supports this assumption.

Limitations and Delimitations

Limitations and delimitations both curtail the ability of a researcher to apply findings from their study to other settings with different populations (Gay, Mills, & Airasian, 2006). The limitations and delimitations that occur with any study should be acknowledged and described at the outset of the study to ensure that anyone reading the study fully understands the significance of any reported findings.

An important limitation for this study is the violation of the assumption of normality when using parametric testing. The data for this study presented heteroscedasticity rather than homoscedasticity when subjected to a Shapiro-Wilk test (Salkind, 2010; Razali & Wah, 2011). Although t-test modeling can tolerate a violation of normality, which is quite common in data collected for educational research, this violation can weaken the generalizability of any significant findings and should be taken into consideration when evaluating the outcomes presented here (Stonehouse & Forrester, 1998; Blanca, Alarcon, Arnau, Bono, & Bendayan, 2017).

The research design also poses a significant limitation on any findings from this study. The research design does not incorporate any manipulation of variables, control groups, or randomization in participant groups all of which would serve to support claims of causality in instructional practices on science content learning. This represents a threat to internal validity as there is no control group for comparison. However, given the ethical considerations surrounding research in education, this limitation is unavoidable.

A final limitation to this study is a lack of knowledge about the participant's previous experiences. Science course work completed by teacher candidates in high school or elsewhere is not known. Science classes taken outside of those required by the elementary teacher program could have a significant impact on how well a preservice teacher could perform on the science subject test used in this study. The addition of this information would strengthen the findings presented by this paper and represent a possible next step in continuing this research.

The delimitating factors of this study are associated with the sample selection, the measurement instrument used, and time period in which the study was conducted. The sample for this study was very specific and narrows the study's scope: preservice elementary teachers enrolled in or having completed a science teaching methods course, who then take the TExES Core Subjects EC-6, Science (804) exam. This specificity of participants is narrowed even more due to the fact that they are all completing the same educator preparation program at a single university. Teacher candidates who complete teacher education preparation programs outside of the university setting or as a part of post-baccalaureate program are not represented in the sample.

Finally, due to the proprietary nature of the testing instrument, it was not available for direct analysis. Only the descriptions of each competency provided by the testing agency can be used when determining which area and topic of science is represented by specific questions. The value of the analyses potentially outweighs this drawback in study design.

Summary

For this study, quantitative analyses of data reported by a teacher certification testing agency was conducted to generate numerical data that was transformed into usable statistics in order to generalize results about teacher content knowledge to the population of pre-service teachers. This chapter details the methodology that was used to design and conduct this study including the purpose, research questions, participants, data sources, collection and analysis methods. The chapter closes with a discussion of the ethical considerations for the study, limitations, and delimitations that impact the scope of the study and have important implications for the generalizability of findings.

CHAPTER 4

RESULTS

Introduction

This chapter details the results from the analyses that were conducted using data collected from the science domain score reports for the TExES Core Subjects EC-6, Science (804) exam. The purpose of this study was to determine the impact of a physical science intervention during a science methods course on the scaled score for the TExES Core Subjects EC-6, Science (804) exam. The physical science intervention, discussed in detail in Chapter 3, included demonstration lessons that targeted the specific topics of buoyancy, density, and dissolving, microteaching, and reflection. With this purpose in mind, this study analyzed data reported by the state testing agency the included a scaled score for the science domain of the exam and questions answered correctly for individual science competencies. The three research questions developed for this study are stated below:

> Research Question 1: Among all participants who made repeat test attempts, is there a statistically significant difference in the TExES Competency 8 and the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention?
>
> Research Question 2: After participation in a physical science intervention, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for repeat test takers who self-identify as Hispanic/Latino and those who self-identify as White/Non-Hispanic for participants?
>
> Research Question 3: Among White/Non-Hispanic participants who made repeat test attempts, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention?

Descriptive Statistics

The distribution of the data used for this study was analyzed to check whether or not the assumption of normality was met. A quartile-quartile (Q-Q) plot was generated to test the normal distribution of scores on the EC-6 TExES Science Subject Test (804) exam. The Q-Q plot for scaled scores indicated that the assumption of normality was violated by the data used for this study. Despite the violation of this assumption, independent samples *t* test modeling was used for analyses for this study based on two considerations: first, the sample size of this study was large and second, the robust nature of t-testing in regards to Type I error rate increases (Stonehouse & Forrester, 1998). The sample for this study consisted of 535 scaled scores recorded from score reports for the EC-6 TExES Science Subject Test (804) exam. The Q-Q plot of the data (scaled scores) used for the comparisons completed for this study is shown in Figure 1.

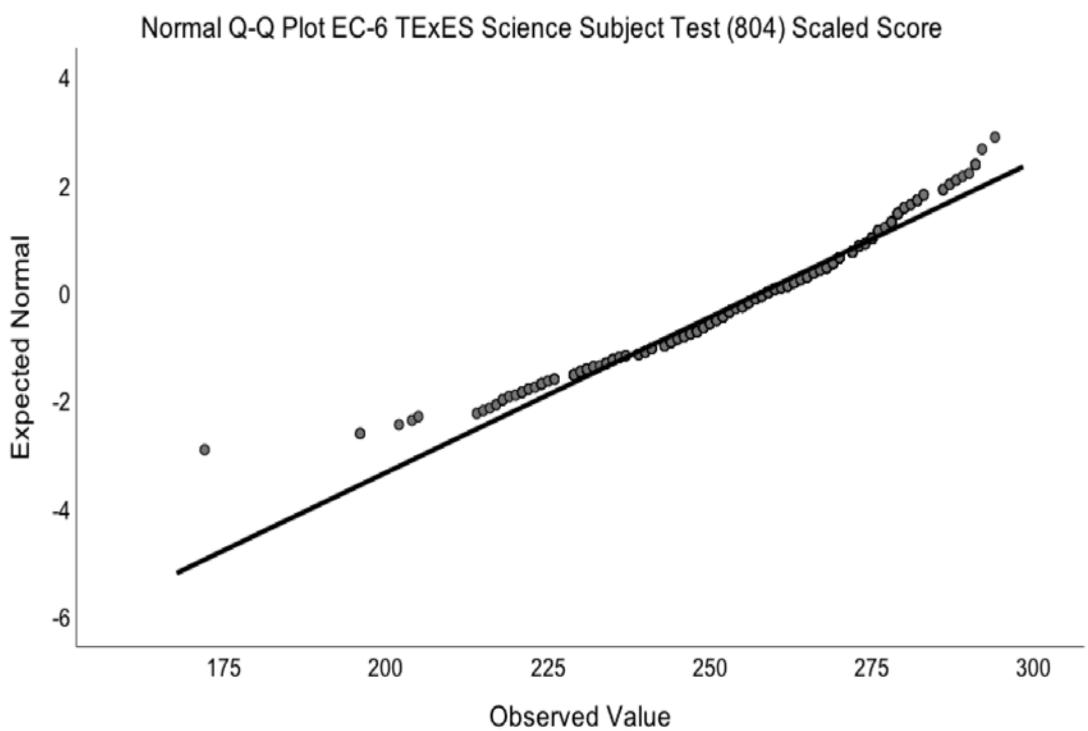

Figure 1. Quantile-quantile plot for EC-6 TExES Core Subjects, Science Test (804) scaled scores indicating non-normality of data.

Descriptive Statistics Competency 8 Calculated Percent Correct

The mean percent correct responses for Competency 8 was the lowest at 69.3% (*N* = 473, *SD* = 25.31%). Competency 10 mean percent correct score was similar but still higher at 71.08% (*N* = 473, *SD* = 34.55%). The standard deviations for these two competencies' mean percent correct responses suggests that the scores for Competency 8 were more tightly clustered around the lower score than for Competency 10 scores. Competency 7 which addressed topics of force and motion had the highest mean percent correct responses score (*MS* = 83.19%, *N* = 473, *SD* = 26.49%) and the mean percent correct score for Competency 9 was lower (*N* = 473, *MS* = 75.95%, *SD* = 23.35%) than 7 but still higher than Competency 8 or 10. Figure 2 gives a summary of the percent calculated correct responses for the competencies that are intended to assess understanding of physical science topics on the TExES Core Subjects EC-6, Science (804) exam.

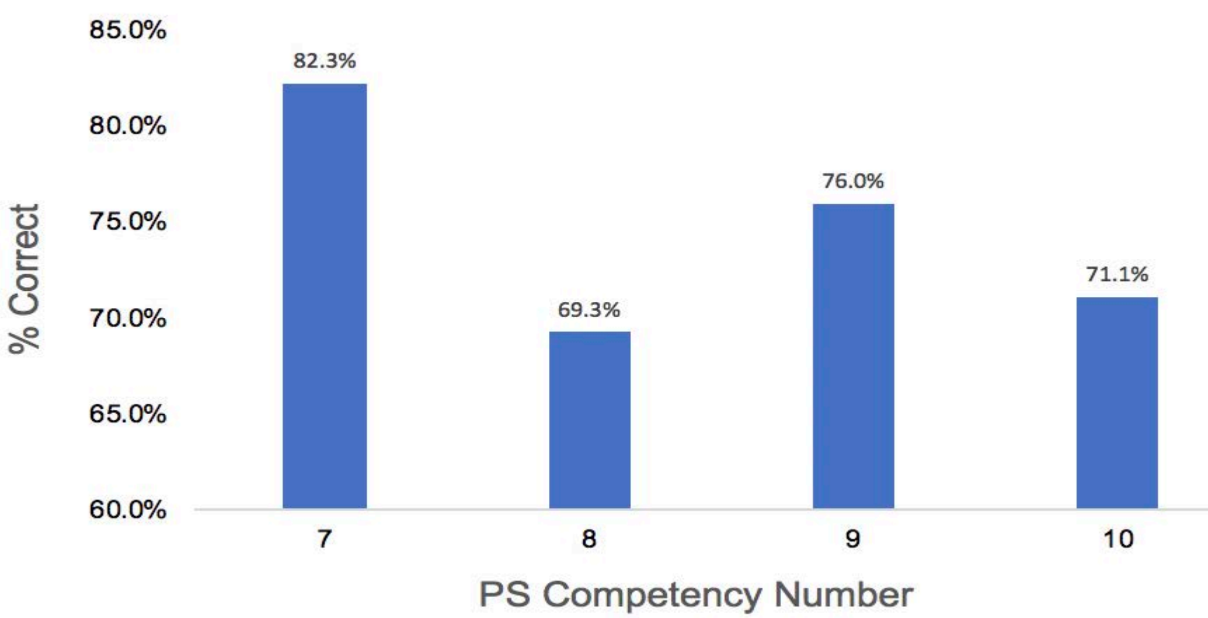

Figure 2. Initial attempts: % correct vs. PS competencies. Competency 7 = force and motion, Competency 8 = Chemical & physical properties of matter, Competency 9 = energy and energy interactions, Competency 10 = energy transformations/conservation

Descriptive Statistics for Participant and Score Characteristics

Out of the 535 score reports, 473 scores were from unique participants who made an initial attempt to pass the TExES Core Subjects EC-6, Science (804) with a scaled score of 240. Of these 473 initial attempts, 48 or 10.1% of participants were not successful in passing the exam. Of the 48 who did not pass the initial attempt, six of the participants (12.5%) did not go on to repeat the exam. The remaining 42 participants completed 62 repeat attempts for a total of 104 attempts (42 unsuccessful initial attempts + 62 repeat attempts = 104 total attempts). Some participants passed the exam on their second attempt while others made a third, fourth, or fifth attempt to pass. Table 2 summarizes these characteristics of the score reports.

Table 2

Descriptive Statistics for All Score Reports TExES EC-6 Core Subjects, Science (804)

	n
Initial + repeat Attempts	535
Initial Attempts	473
Successful Initial Attempts	425
Unsuccessful Initial Attempts	48*
Repeat Attempts	62

*Six of these participants made only an initial failed attempt and did not make repeat attempts

The design of this study also considered the self-reported ethnicity of the participants who completed the TExES Core Subjects EC-6, Science (804) exam. The ethnicities that are reported by TEA were used to group participants' scores for comparison. There were four score reports out of the 535 total attempts that did not include a self-reported ethnic minority group. Hispanic/Latino participants comprised the largest group in this study to self-identify as belonging to an ethnic minority group accounting for 23.9% of all attempts (127 out of 531 participants). The largest group of participants were those self-identified as White/Non-Hispanic accounting for 65.7% (*n* = 349) of all attempts (Table 3). Of the 425 initial passing attempts, these two groups also make up the majority of score reports, with 94 from Hispanic/Latino participants and 282 from White/Non-Hispanic participants.

Table 3

Descriptive Statistics for Study Participants Including Self-Reported Ethnicity

	Self-Reported Ethnicity N	Self-Reported Ethnic Group				
		African American	Asian	Hispanic/ Latino	Two or More Races	White/ Non-Hispanic
Initial + repeat attempts*	531	33	13	127	9	349
Initial passing attempts**	421	25	11	94	9	282
Unsuccessful initial + repeat attempts	104	7	2	32	0	63

*Of these score reports, 4 did not include a self-reported ethnicity (531 + 4 = 535).**Out of these score reports, 4 did not include a self-reported ethnicity (421 + 4 = 425).

Analysis of the scores of participants who made repeat attempts indicated that Hispanic/Latino participants accounted for 32 of the 104 score reports (30.8%), while White/Non-Hispanic participants accounted for 63 (60.6%). In this same group, only 1.9% (*n* = 2) self-identified as Asian and 6.7% (*n* = 7) self-identified as African-American. There were no participants reporting their ethnicity as two or more races who made repeated attempts. Table 3 summarizes the descriptive statistics for self-reported ethnicities for these data sets.

The timing of participation in the physical science intervention in relation to when the attempt was made was also a variable considered when analyses were conducted using both the initial passing attempts data and unsuccessful initial and repeat attempts data. Among the 473 initial passing attempts, 84 were made before participation in the intervention and 389 were made post- intervention. Of the 84 attempts made before the intervention, 73 were passing attempts and 11 were non-passing attempts. One of the 73 passing attempts did not include a self-reported ethnicity and as shown in Table 4 there were 72 initial passing attempts before the intervention. Of the 389 attempts made after the intervention, 352 were passing attempts and 37 were non-passing attempts. However, three participants who made passing attempts after the intervention did not provide a self-reported ethnicity, and for this reason the total ethnicity for participants as shown in Table 4 is 349 (352 – 3 = 349). Table 4 summarizes the details for the initial passing and unsuccessful attempts by each self-reported ethnic group of participants.

Table 4

Descriptive Statistics for Study Participants Initial Attempts with Self-Reported Ethnicity

	Self-Reported Ethnicity N	Self-Reported Ethnic Group				
		African American	Asian	Hispanic/ Latino	Two or More Races	White/ Non-Hispanic
Initial before intervention passing*	72	3	1	9	3	56
Initial before intervention not passing	11	2	0	0	0	9
Initial after intervention passing**	349	22	10	85	6	226
Initial after intervention not passing	37	2	1	16	0	18

Four passing attempts had no reported self-identified ethnicity (469 + 4 = 473). *1 initial passing attempt before the intervention had no reported ethnicity. **Three initial passing attempts after the intervention had no reported ethnicity.

Research Question 1

Research Question 1 examined scores of 42 participants making repeat test attempts to investigate whether or not there was a statistically significant difference in the mean scaled scores of when comparing attempts made before participation in a physical science intervention to attempts made after participation in the intervention. Of these 104 scores from participants who made repeat attempts, 15 were made pre-intervention and 89 attempts were made post-intervention. There were 42 initial attempts, 42 second attempts, 14 third attempts, 5 fourth attempts, and 1 fifth attempt. Table 5 summarizes the descriptive data for participants making repeat attempts to pass the TExES Core Subjects EC-6, Science (804) exam.

As shown in Table 5, one Asian participant tested twice. Three African American participants tested a total of seven times two participants tested twice and a third participant tested three times. A total of 15 Hispanic/Latino participants tested a total of 32 times with 13 participants testing twice and two participants testing three times. Twenty-three White/Non-Hispanic participants engaged in a total of 63 testing attempts with 12 participants testing twice, six participants tested six times, four participants tested four times, and one participant tested a total of five times. Of all participants who retested only one participant did not ultimately pass the exam.

Table 5 also includes the mean calculated score for the percent correct responses for questions in Competency 8, which addresses the topics of buoyancy, density, and dissolving. These topics were the focus of the demonstration lessons delivered to participants by the science methods course faculty as a part of the physical science intervention.

Table 5

Multiple Attempts Self-Reported Ethnicity, Scaled Scores, % Correct Competency 8

Ethn.	Attempt 1		Attempt 2		Attempt 3		Attempt 4		Attempt 5	
	Score	Comp8	Score	Comp8	Score	Comp8	Score	Comp8	Score	Comp8
Afr Amer	196*	25%	172*	0%	218**	50%				
Afr Ame.	222*	67%	246**	50%						
Afr Amer	230*	100%	252**	100%						
Asian	234**	33%	250**	33%						
Hispan	226**	100%	249**	33%						
Hispan	225**	67%	272**	50%						
Hispan	221**	100%	253**	100%						
Hispan	205**	67%	220**	67%						
Hispan	231**	33%	241**	50%						
Hispan	234**	67%	249**	100%						
Hispan	219**	33%	245**	100%						
Hispan	222**	50%	251**	67%						
Hispan	230**	33%	241**	67%						
Hispan	224**	50%	256**	25%						
Hispan	236**	33%	237**	0%	256**	25%				
Hispan	231**	0%	243**	67%						
Hispan	229**	0%	247**	33%						
Hispan	223**	100%	216**	100%	249**	75%				
Hispan	215**	67%	234**	67%						
White	229**	0%	218**	33%	253**	67%				

(table continues)

Ethn.	Attempt 1		Attempt 2		Attempt 3		Attempt 4		Attempt 5	
	Score	Comp8	Score	Comp8	Score	Comp8	Score	Comp8	Score	Comp8
White	202**	67%	234**	67%	224**	50%	235**	25%	243**	100%
White	232**	100%	218**	25%	229**	67%	252**	67%		
White	234**	67%	257**	100%						
White	236**	33%	256**	25%						
White	214*	25%	232**	0%	257**	0%				
White	217*	50%	246**	50%						
White	196*	0%	204*	67%	255**	67%				
White	231*	100%	265**	50%						
White	236*	50%	226*	67%	231*	50%	270**	67%		
White	234**	100%	262**	50%						
White	236*	50%	235*	67%	245*	50%				
White	231**	33%	240**	67%						
White	235**	0%	251**	67%						
White	234**	67%	251**	67%						
White	239**	33%	224**	33%	251**	50%				
White	239**	100%	258**	67%						
White	224**	67%	240**	100%						
White	221**	33%	259**	100%						
White	224**	33%	269**	100%						
White	239**	33%	229**	33%	229**	67%	263**	33%		
White	226**	67%	237**	67%	235**	100%	248**	100%		
White	221**	67%	233**	0%	255**	100%				

*Pre-intervention attempt. **Post-intervention attempts

The mean percent correct score for attempts made after the intervention (*MS* = 57.7%, *SD* = 29.8%) was higher than the mean score for attempts made before the intervention (*MS* = 44.4%, *SD* = 29.2%). The difference in these means scores did not reach the level of statistical significance used for this study (t = -1.60, df = 102, p = .114). After participation in the intervention, eleven of 15 Hispanic/Latino participants received a higher or the same percent correct score for Competency 8 on the second attempt (73%), while four showed a decline. Sixteen of 23 or 70% of White/Non-Hispanic participants received a higher or the same percent correct score for Competency 8 on the second attempt, while seven showed a decline. Fourteen candidates tested more than twice and eight of these candidates maintained or increased their score over time. This information might be of interest given that Competency 8 was the only one of the four physical science competencies to show a higher mean calculated percent score after the intervention.

t Test Results Research Question 1

Research Question 1 asked whether or not there is a statistically significant difference between the scores of all participants who made multiple attempts to pass the EC-6 Core Subjects, Subject Test IV (804) exam when scores were compared for pre-intervention and post-intervention intervention attempts. The results of an independent samples *t*-test indicated the difference between the mean scores for these two groups was statistically significant (t = -4.21, df = 102, p<.001). The mean score for pre-intervention attempts was lower at 219.73 (n = 15, *SD* = 20.04) while the mean score for post-intervention was higher at 238.24 (n = 89, *SD* = 14.93). The sample size for this comparison was not equal; however, the homogeneity of variances assumption was not violated. This finding suggests that the physical science intervention implemented as part of the science methods course for this study had a positive impact on the scaled scores for these participants. The results for the analysis for Research Question 1 summarized in Table 6.

Table 6

Independent Samples t*-Test Results for Pre-Intervention and Post-Intervention Scaled Scores from All Participants Making Multiple Attempts*

	n	*MS*	*SD*	95% CI for Mean Difference	*t*	*df*
Pre-intervention attempt	15	219.72	20.04	-27.21, -9.79	-4.21*	102
Post-intervention attempts	89	238.24	14.93			

*p<.001

Research Question 2

Research Question 2 examined the post- intervention scores of Hispanic/Latino and White/Non-Hispanic participants who made repeat attempts on the TExES Core Subjects EC-6, Science (804) exam. Before proceeding with this comparison, initial passing attempts by the two groups after participation in the physical science intervention were compared to see if there was a significant difference between the mean scaled scores for the TExES EC-6 Core Subjects, Science (804) exam. Of the 473 initial attempts, 85 passing attempts were made by Hispanic/Latino participants after participation in the physical science intervention and 226 passing attempts were made by White/Non-Hispanic participants after participation in the physical science intervention. The mean scaled scores for post-intervention attempts was 259.82 (*SD* =

12.04) for Hispanic/Latino participants and 264.12 (*SD* = 11. 91) for White/Non-Hispanic. Table 7 summarizes these descriptive statistics.

Table 7

Initial Passing Attempts Hispanic/Latino and White/Non-Hispanic Post-Intervention Scaled Scores

Participant Group	*n*	*MS*	*SD*
Hispanic/Latino Post-Intervention	85	259.82	12.04
White/Non-Hispanic Post-Intervention	226	264.12	111.92

Next, the scores for initial unsuccessful attempts and repeat attempts were compared for Hispanic/Latino and White/Non-Hispanic participant groups after the intervention. Of the 104 scores that comprise initial unsuccessful and repeat attempts, 83 were post- intervention attempts. White/Non-Hispanic participants accounted for 51 of these attempts (12 scores from White/Non-Hispanic participants were pre-intervention) and 32 were from Hispanic/Latino participants (no Hispanic/Latino participants in this group took the exam pre- intervention). Descriptive statistics for post- intervention scores for Hispanic/Latino and White/Non-Hispanic participant's initial unsuccessful attempts and repeat attempts are shown in Table 8

Table 8

Post- Intervention Scaled Scores Hispanic/Latino and White/Non-Hispanic Participants with Multiple Attempts

Participant Group	*n*	*MS*	*SD*
Hispanic/Latino Post-Intervention	32	235.31	14.86
White/Non-Hispanic Post-Intervention	51	240.06	15.13

*12 scores for this participant group were for attempts made before participation in the intervention *t* Test Results Research Question 2

Among all initial scaled scores, post- intervention attempts by Hispanic/Latino participants were compared to post- intervention attempts by white/Non-Hispanic participants. An independent samples *t* test comparison of the means indicated there was a statistically significant difference between the two groups' scaled scores (t = 4.03, df = 343, p <.000) with the mean scaled score for Hispanic/Latino participants (MS = 259.82, SD = 12.04) lower than the mean scaled score for White/Non-Hispanic participants (MS = 264.12, SD = 11.92). However, among participants that failed the initial attempt and made repeat attempts, there was no statistically significant difference between the scores for Hispanic/Latino participants (MS = 235.31, SD = 14.86) and White/Non-Hispanic participants (MS = 240.06, SD = 15.13) when post- intervention attempt scores were compared (t = -1.40, df = 81, p = .165). As in the previous analysis, the sample sizes were not equal for these comparisons but the homogeneity of variance assumption was not violated. The results of these analyses are summarized in Table 9.

Table 9

Independent Samples t-*Test Results Post-Intervention Scaled Scores Hispanic/Latino and White/Non-Hispanic Initial and Repeat Attempts*

	Hispanic/ Latino			White/Non-Hispanic			95% CI for Mean Difference	*t*	df
	n	*MS*	*SD*	*n*	*MS*	*SD*			
Initial passing attempts	85	259.82	12.04	226	264.12	11.92	-7.29, -1.30	-2.83*	309
Initial failing + repeat attempts	32	235.31	14.86	51	240.06	15.13	-11.50, -2.0	-1.40**	81

*p = .005. **p = .165

Research Question 3

The pre- and post- intervention scores for White/Non-Hispanic participants who made repeat attempts on the TExES Core Subjects EC-6, Science (804) exam were compared to investigate Research Question 3. This analysis was possible because there was an adequate number of scores that were from pre- and post- intervention attempts for comparison. There were 12 scores from White/Non-Hispanic participants who took the exam before participating in the physical science intervention and 51 scores from White/Non-Hispanic participants who took the exam after participation in the intervention. For this group of participants, the mean pre-intervention scaled score was 225.50 (*SD* = 14.71) and the post- intervention score was 240.06 (*SD* = 15.13). The descriptive statistics for this comparison are shown in Table 10.

Table 10

White/Non-Hispanic Participants Pre- and Post-Intervention Scaled Scores Multiple Attempts

Participant Group	*n*	*MS*	*SD*
Pre-intervention	12	225.50	14.71
Post-intervention	51	240.06	15.13

t Test Results Research Question 3

Table 11 shows the results from the independent samples *t* test indicated that White/Non-Hispanic participants' scores increased significantly on attempts made after the physical science intervention compared to scores for attempts made before participation in the physical science intervention (t = -3.01, df = 61, p = .004). The difference in mean scores was substantial which supports the continued use of the physical science intervention especially for participants who make repeat attempts to pass the science domain of the initial certification exam for preservice elementary teachers.

Table 11

Independent Samples t-*Test Results White/Non-Hispanic Participants Pre- and Post-Intervention Scaled Scores Making Multiple Attempts*

	n	*MS*	*SD*	95% CI for Mean Difference	*t*	*df*
Pre-intervention	12	225.50	14.71	-24.22, -4.90	-3.01*	61
Post-intervention	51	240.06	15.13			

*p = .004

Summary

This chapter provided a detailed description of analyses conducted to test each of the three research questions for this study. While the assumption of normality was not met, the large sample size and the robustness of the statistical test used for analyses of the data ensures the results reported here can be used to draw conclusions on the efficacy of the physical science intervention that was included as a part of the science methods course.

CHAPTER 5

CONCLUSIONS

The difficulty that preservice and inservice teachers encounter with understanding science concepts is well established by the literature examined in this paper (Anggoro, Widodo, & Suhandi, 2017; Crawley & Arditzoglou, 1988; Ginns & Waters, 1995; Forbes, Sabel, & Zangori, 2015; Harrell & Subramaniam, 2014, 2015; Papadouris, Hadjigeorgiou, & Constantinou, 2014; Potvin & Cyr, 2017; Rice, 2005; Stein, Larrabee, & Barman, 2008; Trumper, 1997).

The purpose of this was study to address one area of difficulty in particular, physical science, with an intervention and look for evidence of the intervention's efficacy. The findings presented here combined with the description of the process of the intervention presents a potentially effective means for teacher educators to assist their preservice elementary teachers in mastery of physical science content. This is the goal of educational researchers whose work was discussed in the review of literature as they continue to look for the best ways to assist their preservice elementary teachers in passing the science exam for certification (Crawley & Arditzoglou, 1988, December; Ernst, 1994; Hawkins & Rogers, 2016; Hrepic, et al, 2005 August 10-11; Koc & Yager, 2016; Koenig, Schen, & Bao, 2012; Mesci & Schwartz, 2017). The results presented in this chapter showed the impact of a targeted science intervention that was delivered to participants during a science methods course that occurred immediately before a semester of student teaching.

Conclusion for Research Question 1

The following question is the first for three research questions addressed in this study. Among all participants who made repeat test attempts, is there a statistically significant difference in the TExES Competency 8 and the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention?

In addressing the research question, descriptive data were collected for each participant including ethnicity, and the number of testing attempts as well as individual TExES test scores and raw data for TExES Competency 8, the teacher understands the physical and chemical properties of and changes in matter. All testing dates as well as the semester the student enrolled in a science methods course was collected.

A comparison of scores was performed for all participants who made repeated attempts to pass the TExES EC-6 Core Subjects, Subject Test IV (804). Results showed that the mean score for Competency 8 was higher (MS = 57.7%, SD = 29.8%) than the mean score for test attempts before the intervention (MS = 44.4%, SD = 29.2%). However, the difference in these means scores did not reach the level of statistical significance used for this study ($t = -1.60$, $df = 102$, $p = .114$).

Even when analysis of data from a source outside the educator program does not produce statistically significant results, the findings can be of practical significance as evidenced by the increase in mean scores found for Competency 8 which provided important information to the educational researchers designing interventions. Paying close attention to all the data in the context of the study is a better approach that relying solely on statistically significant data. As Kirk stated in 1996, "…identical treatment effects can lead to difference decisions" if based solely on a selected alpha level (p5). Bearing this in mind, the changes in the mean in percent correct scores when comparing pre- and post- intervention scores can serve as a helpful way to assess the level of conceptual understanding for science topics among preservice science teachers.

After participation in the intervention 73% of Hispanic/Latino participants and 70% of White/Non-Hispanic participants who retested received a higher percent correct score or the same percent correct score for Competency 8. These results suggest that the content knowledge acquired as a result of the intervention contributed to the passing score and had an enduring impact on the content knowledge of participants. Moreover, the impact of Competency 8 on the overall test scaled score was statistically significant ($t = -4.21$, $df = 102$, $p<.001$).

Conclusion for Research Question 2

The second research question examined in this research study was: After participation in a physical science intervention, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for repeat test takers who self-identify as Hispanic/Latino and those who self-identify as White/Non-Hispanic for participants?

This research question utilized a subset of Research Question 1 data specific to Hispanic/Latino and White/Non-Hispanic participants. Descriptive data were collected for each participant including ethnicity, and the number of testing attempts as well as individual TExES test scores and raw data for TExES Competency 8, the teacher understands the physical and chemical properties of and changes in matter. All testing dates as well as the semester the student enrolled in a science methods course was collected.

Because test repeaters who were Hispanic/Latino participants did not test before the intervention, Research Question 2 examined a comparison between post-intervention results for Hispanic/Latino and White/Non-Hispanic participants. The initial post-intervention attempts showed there was a statistically significant difference between the two groups with White/Non-Hispanic participants presenting higher scores compared to Hispanic/Latino participants ($t = 4.03$, $df = 343$, $p <.000$). This result is supported by many studies showing the impact of standardized testing on minority teacher candidates (Angrist & Guryan, 2006; Ahmed & Boser, 2014; Carver-Thomas, 2018; Goodman, Arbona, & Rameriz, 2008). However, among participants that failed the initial attempt and made repeat attempts, there was no statistically significant difference between the scores for Hispanic/Latino participants (MS = 235.31, SD = 14.86) and White/Non-Hispanic participants (MS = 240.06, SD = 15.13) when post-intervention attempt scores were compared ($t = -1.40$, $df = 81$, $p = .165$). These results suggest that repeat test takers benefited significantly from the intervention as it closed the gap and leveled the field for Hispanic/Latino participants. In this study 35.7% of repeat test takers were Hispanic/Latino participants who failed the initial attempt on the TExES Core Subjects EC-6 Science (804) exam. This finding aligns with the results of other studies that indicated a positive impact on the science content knowledge of preservice teachers who completed science courses that also included interventions (Akerson, Morrison, & McDuffie , 2005; Long, Harrell, Subramaniam, & Pope, 2019; Papadouris, Hadjigeorgiou & Constantinou, 2014; Trumper, 2003; Trundle, Atwood, &

Christopher, 2007). This finding is also important as those participants who must make multiple attempts to pass the science subject test for certification have a great need for an intervention designed to target areas of content knowledge weakness. After the intervention, all but two participants were able to pass the certification exam.

In as much as this study did not interview candidates, the reasons to cease testing after the second attempt is unknown. In Texas, by law, candidates may test a total of five times before they are denied further test permissions.

Conclusion for Research Question 3

The third research question addressed by this study was: Among White/Non-Hispanic participants who made repeat test attempts, is there a statistically significant difference in the scaled score for the TExES Core Subjects EC-6, Science (804) exam for participant test attempts made before and after participation in a physical science intervention? Twenty-three of forty-two participants who retested self-identified as White/Non-Hispanic (51%). The results of this study show that White/Non-Hispanic participants who failed their initial test attempt significantly increased their score after the intervention (pre-intervention scaled score was 225.50 ($SD = 14.71$) and the post-intervention score was 240.06 ($SD = 15.13$) and this increase in score was statistically significant ($t = -3.01$, $df = 61$, $p = .004$). Approximately 65% of participants who retested either passed the TExES Core Subjects EC-6, Science (804) exam or improved their scaled score and 44% of these participants increased the percentage of correct answers for TExES Competency 8. This finding also aligns with the results of other studies that indicated a positive impact on the science content knowledge of preservice teachers who completed science courses that also included interventions (Akerson, Morrison, & McDuffie , 2005; Long, Harrell, Subramaniam, & Pope, 2019; Papadouris, Hadjigeorgiou & Constantinou, 2014; Trumper, 2003; Trundle, Atwood, & Christopher, 2007). Tightly focused content knowledge interventions can diminish the number of candidates who must make multiple attempts to pass the science subject test for certification. Such interventions are important in that time and expense is involved in retesting. Placing these interventions designed to target areas of content knowledge weakness within a science methods course helps to activate knowledge that is no longer in the candidate's short term memory. It can also help candidates to create new knowledge that is aligned with curricular standards and contextualized within pedagogical content knowledge.

These findings illustrate the utility of competency data reported in the TExES EC-6 Core Subjects, Subject Test IV (804) score report for generating useful statistical data to better understand the science content knowledge of pre-service elementary teachers. For each of the areas of science, those concepts that presented the greatest difficulty for participants were identified along with areas that show improvement in science content knowledge over the course of the study. This information can be used to for continued efforts to improve the existing intervention and to design future interventions.

Implications for Science Teacher Educators

As Akerson, Morrison, and Mc Duffie (2006) pointed out, many preservice elementary teachers have completed only a small number of science courses before entering a science methods course which does not prepare them to teach science themselves. This point is supported by findings that inservice elementary teachers avoid delving deeply into science concepts addressed by science lessons and instead focus on the activities (Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2013). According to Kaya (2013), even for those teachers who take more science content courses before entering the science methods course, have misconceptions about science are resistant to change and must be addressed. Santu, Marten-Rivera, Bovis, and Orend (2014) suggest the science methods course presents an opportunity to shore up the conceptual understanding of preservice elementary teachers. This opportunity can be realized by the inclusion of interventions aimed at addressing topics that prove particularly difficult for preservice elementary teachers.

PS Interventions

The results of this study provide support the recommendations for more explicit instruction on science content in methods courses. Some examples of such recommendations include Akerson, Morrison, and McDuffie (2005) pointing out the need for explicit instruction on the nature of science, while Trumper (2003) and Trundle, Atwood and Christopher (2007) highlight content knowledge deficits in Earth/space science, and Papadouris, Hadjigeorgiou, and Constantinou (2014) provide the same recommendations for energy concepts. The use of demonstration lessons taught by teacher educators who have experience teaching science coupled with microteaching experiences and cycles of reflection by the preservice teacher proved to be a successful way to accomplish the goal of explicit instruction.

The methods of analysis applied to the data used for this study also demonstrate a way that faculty can enhance the continuous-evaluation of the educator preparation program discussed by Feuer, Floden, Chudowsky (2103) and Akerson, Pongsanon, Rogers, Carter, and Galindo (2015). Continual improvement through self-evaluation of the instruction designed for preservice elementary teachers is necessary if teacher educators are to ensure their program's success in the face of increasing pressures from accreditation agencies that rely heavily on teacher certification scores (von Hippel, Bellows, Osborne, & Lincove, 2016).

Addressing Diversity

Research Question 2 concerns the effectiveness of the physical science intervention on the scores of participants on the TExES Core Subjects EC-6 Science (804) exam and TExES Competency 8 who self-identify as belonging to different self-reported ethnic groups. While research reports that targeted intervention such as the one used for this study are effective in increasing the content knowledge of preservice elementary teachers, findings have also indicated that there is a difference between scores on teacher certification tests when comparing scores from preservice teachers who identify as belonging to an ethnic minority to those who do not (Goodman, Arbona, & Rameriz, 2008). Angrist and Guryan (2006) reported findings indicating that certification testing eliminates Hispanic/Latino teacher candidates at a higher rate than White/Non-Hispanic testers. The effect of this is fewer teachers from ethnic minorities in the classroom, while Increases in cut scores discussed earlier in chapter two will exacerbate this problem (Ahmed & Boser, 2014; Goodman, Arbona, & de Ramirez, 2008; Shuls, 2008). To investigate whether or not the physical science intervention used for this study was effective in addressing that disparity in certification test scores, an analysis was made comparing these two groups of participants who made multiple attempts on the exam post-intervention.

The findings from this study are also important in that they indicated there were no significant differences between participant scaled scores on the TExES Core Subjects EC-6, Science (804) exam of participants who self-identify as Hispanic/Latino and those who identify as White/Non-Hispanic. Specifically, among participants that made repeat attempts on the exam, there was no statistical significance found when comparing the scaled scores or the mean percent correct responses for TExES Competency 8 for participants who identified as Hispanic/Latino and those who identified as White/Non-Hispanic. Close examination of data aimed at developing ways to help reduce any mean difference in certification exam scores could be beneficial in reducing the barriers that have kept a larger number of teachers from ethnic minority groups out of the classroom (Ahmed & Boser, 2014; Carver-Thomas, 2018). In the context of this study, the population at the university where this research was conducted is diverse in terms of the self-reported ethnicities of students. This underscores the usefulness of this study's finding for other programs that also train a diverse group of preservice teachers (Long, Harrell, Subramaniam, & Pope, 2019). As the lack of diversity in the teaching force in the United States continues to persists, it is imperative that efforts continue to be made to meet the needs of all the students who seek to become educators (Barmore, 2016; Goldhaber, Liddle, & Theobold, 2013).

Intervention Targets

Several studies discussed in the literature review identified the more challenging science for preservice elementary teachers using pre- and post- testing conducted at the beginning and end of a science methods courses (Forbes, Sabel, & Zangori, 2015; Hrepic, 2006; Menon & Sadler, 2016; Cervato & Kerton, 2017; Santu, Maerten-Rivera, Bovis & Orend, 2014). Another way to identify those difficult topics is suggested in this paper. The results of this study demonstrated that analyses of data from specific competencies reported on the certification exam score report were useful to the science teacher educator in identifying which specific concepts continue to present the most difficulty for preservice elementary teachers. Calculating and comparing the percent correct score for each competency combined with the detailed descriptions of the topics from the accreditation agency administering the certification exam for this study permitted the faculty of the science methods course to focus their intervention demonstration lessons on topics of greatest need. This analysis of score report data helped to uncover information that is helpful, but not apparent by looking only at a scaled score for the science test.

Zigo and Moore (2003) reported on the difficulties encountered when attempting to prepare preservice teachers for a certification exam to which their access was very limited. The results of this study provide evidence for the value of examining data generated by a test score report to develop interventions that have a positive impact on the scores of preservice elementary teachers on the science portion of their certification exams. Further, this type of analyses of competency data could be performed in repeating cycles to track not only what preservice elementary teachers understand the best, but also might indicate shifts in the certification exam itself prompting additional changes to teacher instruction.

Implications for Teacher Professional Development

Beyond the immediate problem of not passing a science subject test required for certification, teachers without adequate science content knowledge may struggle to teach concepts they do not fully understand (Rice, 2005). These teachers incorporate science activities into their classroom as required, but have difficulty addressing their own students' misconceptions and are unable to tailor the lessons to fit their students' needs (Davis, 2006; Nilsson, 2008). For teachers already in practice, the cycle of teaching and reteaching to an audience of peers would be helpful in closing gaps that remain in their own science content knowledge (Lewis & Tsuchida, 1999). Carefully planned, teacher development training sessions could incorporate teaching lessons to other teachers who can provide useful feedback through the pairing of elementary teachers with middle school or secondary science teachers in an effort to increase science content knowledge of specific topics.

In this case, a much clearer picture has emerged of what preservice teachers in this educator training program understand about science as well as where gaps remain that may be responsive to further intervention. Literature on teacher effectiveness and teacher quality reports in an increase in the use of student achievement along with certification rates of classroom teachers to evaluate teacher certification program (Hanushek, Kain, O'Brien, & Rivkin, 2005; Goldhaber, 2007; Shuls, 2018; von Hippel, Bellows, Osborne, Lincove, & Mills, 2016). However, once the teacher is already in the classroom teaching their own students, there is no longer an opportunity for targeted interventions to address gaps in content knowledge which can still have an impact on the assessment of the educator preparation program. This study presents findings that can be used to improve inservice teacher trainings that are developed by those who design and deliver professional development.

Limitations

The type of analysis presented here is only possible with detailed score reports which may not be available to some faculty who teach the science methods course for their teacher education program. The structure of score reports may vary depending on the certification granting agency. Beyond science, other subject tests' score reports may not provide enough detail for application of this research even when detailed score reports are available. Additionally, if competency descriptions are broad and cannot be used to narrow down the scope of questions asked on a certification exam, the analyses that can be conducted on certification exam data are limited.

The types of analyses used for this study are not useful in the absence of knowledge of interventions currently in place in the science methods course even if detailed score reports are available. The ability to look at the results and connect them with instructional practices is essential to making use of any findings that may be uncovered. While education providers receive data about the number of candidates passing certification examinations, understanding the context in which such knowledge is acquired is essential for implementing beneficial changes. Faculty who design and deliver the instruction to preservice teachers must be involved in analyses to maximize the usefulness of any findings.

Recommendations for Future Research

The results of this study suggest that the same type of analyses could be useful when applied to future educational research endeavors. Expanding the score of science competencies beyond physical science, looking at populations of preservice teachers outside of the traditional university educator preparation program, and the inclusion of additional participant variables could prove to helpful in developing effective intervention that aim to increase conceptual understanding of topics that are assessed by teacher certifications programs.

Other Science Competencies

Beyond physical science content understanding and the intervention delivered to target it, results presented here have important implications for life science and Earth/space science concepts as well. Using the same type of analyses for data from the competencies that are covered in these areas, teacher educators could gain useful insight into which topics present the greatest difficulty for preservice teachers and help them to design their interventions accordingly. Detailed descriptions of interventions used for concepts in life and Earth/space science could be done to make use of the data for these competencies.

Other Paths to Teaching

A significant portion of the preservice teachers in this study gained certification by completing a post-baccalaureate program. These participants' data was not used for the analyses presented by this study. Future studies that are able to incorporate post-baccalaureate certification program data would be helpful as the number of teachers who pursue a non-traditional path to teacher certification grows. In the state where this study was conducted a sizable portion of teachers are certified after obtaining a bachelor's degree in a field outside of teaching and return to complete the education courses required for certification. Among these preservice teachers, there is a great deal of variation in course background, including science courses (Friedrich, 2014).

Targeted interventions could benefit preservice teachers enrolled in programs outside of the university and represent an opportunity for researchers to further measure the effectiveness of the specific intervention used for this study. This would be a valuable addition to teacher educator literature as it would give insight into the science content knowledge of a large portion of preservice and inservice teachers that so far have received much more limited attention in educational research. For geographical areas where the number of alternatively certified teachers is high, this could prove be valuable.

More Variables for Study

This study looked at the impact of an intervention considering only a small number of participant characteristic variables. If more detailed profiles of the participants science course work could be obtained, more specific analyses could be conducted to better explain the variance in scores. To accomplish this, researchers could include a survey for their preservice elementary teachers to be completed at some point during the science methods course. This survey instrument would be particularly useful if it included a list of science courses taken prior to the enrollment in the methods course as well as high school science courses. This information could be used to determine which interventions could be more beneficial for specific populations of preservice teachers.

Understanding how important science content knowledge is to science teaching effectiveness, is valuable to uncover data that allows teacher educators to modify the content of the lessons that are a part of the science methods course. The information learned from this study can be helpful to teacher educators who are either in need of a helpful intervention for these topics or looking to improve or expand an existing intervention. The reality of the reliance of certification granting agencies on the use of standardized testing does not show signs of diminishing any time soon. Although educators know full well the limitation of standardized testing to assess the knowledge of any student, teachers of educators would be wise to make use of data they do generate when planning their own instruction. The field of teacher preparation for certification is dynamic with changes that can occur as often as new legislative sessions that implement changes to educator preparation program guidelines. Any information that is readily available to better meet the needs of preservice teachers should be utilized to that end.

APPENDIX A

COMPETENCY DESCRIPTIONS FOR TExES CORE SUBJECTS EC-6 SCIENCE

(804) TEST

Competency	Description
Competency 007 (Forces and Motion): The teacher understands forces and motion and their relationships.	The beginning teacher: A. Demonstrates an understanding of the properties of universal forces (e.g., gravitational, electrical, magnetic). B. Understands how to measure, graph and describe changes in motion by using concepts of position, direction of motion and speed. C. Analyzes the ways unbalanced forces acting on an object cause changes in the position or motion of the object. D. Analyzes the relationship between force and motion in a variety of situations (e.g., simple machines, geologic processes).
Competency 008 (Physical and Chemical Properties): The teacher understands the physical and chemical properties of and changes in matter.	The beginning teacher: A. Describes and measures the physical and chemical properties of substances (e.g., size, shape, temperature, magnetism, hardness, mass, conduction, density). B. Describes the physical properties of solids, liquids and gases. C. Distinguishes between physical and chemical changes in matter. D. Applies knowledge of physical and chemical properties (including atomic structure) of and changes in matter to processes and situations that occur in life and in earth and space science. E. Distinguishes between elements, compounds, mixtures and solutions and describes their properties. F. Describes and explains the occurrence and importance of a variety of chemical reactions that occur in daily life (e.g., rusting, burning of fossil fuels, photosynthesis, cell respiration, chemical batteries, digestion of food).
Competency 009 (Energy and Interactions): The teacher understands energy and interactions between matter and energy.	The beginning teacher: A. Understands conservation of energy and energy transformations and analyzes how energy is transformed from one form to another (e.g., potential, kinetic, mechanical, sound, heat, light, chemical, electrical) in a variety of everyday situations and how increasing or decreasing amounts affect objects. B. Understands the basic concepts of heat energy and related processes (e.g., melting, evaporation, boiling, condensation, conduction, convection, and radiation). C. Understands the principles of electricity and magnetism and their applications (e.g., electric circuits, electromagnetic fields, motors, audio speakers, lightning). D. Applies knowledge of properties of light (e.g., reflection, refraction) to describe the functioning of optical systems and phenomena (e.g., camera, microscope, rainbow, eye). E. Demonstrates an understanding of the properties, production, and transmission of sound.
Competency 010 (Energy Transformations and Conservation): The teacher understands energy transformations and the conservation of matter and energy.	The beginning teacher: A. Describes sources of electrical energy and processes of energy transformation for human uses (e.g., fossil fuels, solar panels, hydroelectric plants). B. Applies knowledge of transfer of energy in a variety of situations (e.g., the production of heat, light, sound and magnetic effects by electrical energy; the process of photosynthesis; weather processes; food webs; food and energy pyramids). C. Understands applications of energy transformations and the conservation of matter and energy in life and in earth and space science.

Competency	Description
Competency 011 (Structure and Function of Living Things): The teacher understands the structure and function of living things.	The beginning teacher: A. Understands that living systems have different structures that perform different functions. B. Understands and describes stages in the life cycles of common plants and animals (including animals that experience complete and incomplete metamorphosis). C. Understands that organisms have basic needs. D. Analyzes how structure complements function in cells, tissues, organs, organ systems and organisms. E. Identifies human body systems and describes their functions. F. Understands the relationship between characteristics, structures, and functions and corresponding taxonomic classifications.
Competency 012 (Reproduction and the Mechanisms of Heredity): The teacher understands reproduction and the mechanisms of heredity.	The beginning teacher: A. Describes the processes by which plants and animals reproduce and explains how hereditary information is passed from one generation to the next. B. Compares and contrasts inherited traits and learned characteristics. C. Understands the organization of hereditary material and how an inherited trait can be determined by one or many genes and how more than one trait can be influenced by a single gene. D. Distinguishes between dominant and recessive traits and predicts the probable outcomes of genetic combinations. E. Evaluates the influence of environmental and genetic factors on the traits of an organism.
Competency 013 (Adaptations and Evolution): The teacher understands adaptations of organisms and the theory of evolution.	The beginning teacher: A. Demonstrates knowledge of adaptive characteristics and explains how adaptations influence the survival of populations or species. B. Describes how populations and species change through time. C. Describes processes that enable traits to change through time, including selective breeding, mutation and other natural occurrences.
Competency 014 (Organisms and the Environment): The teacher understands the relationships between organisms and the environment.	The beginning teacher: A. Understands that organisms respond to internal or external stimuli and analyzes the role of internal and external stimuli in the behavior of organisms. B. Understands relationships between organisms and the environment and describes ways that living organisms depend on each other and on the environment to meet their basic needs. C. Identifies organisms, populations or species with similar needs and analyzes how they compete with one another for resources. D. Analyzes the interrelationships and interdependence among producers, consumers and decomposers in an ecosystem (e.g., food webs, food chains, competition, predation). E. Identifies factors that influence the size and growth of populations in an ecosystem. F. Analyzes adaptive characteristics that result in a population’s or species’ unique niche in an ecosystem. G. Knows how populations and species modify and affect ecosystems.

Competency	Description
Competency 015 (Structure and Function of Earth Systems): The teacher understands the structure and function of Earth systems.	The beginning teacher: A. Understands the structure of Earth and analyzes constructive and destructive processes (including plate tectonics, weathering and erosion) that produce geologic change, including how these processes have affected Earth history. B. Understands the form and function of surface water and groundwater. C. Applies knowledge of the composition and structure of the atmosphere and its properties. D. Applies knowledge of how human activity and natural processes, both gradual and catastrophic, can alter Earth systems.
Competency 016 (Cycles in Earth Systems): *The teacher understands cycles in Earth systems.*	The beginning teacher: A. Understands the rock cycle and how rocks, minerals and soils are formed, and their respective properties. B. Understands the water cycle and its relationship to weather processes. C. Understands the nutrient (e.g., carbon, nitrogen) cycle and its relationship to Earth systems. D. Applies knowledge of how human and natural processes affect Earth systems. E. Understands and describes the properties and uses of Earth materials (e.g., rocks, soils, water, atmospheric gases).
Competency 017 (Energy in Weather and Climate): *The teacher understands the role of energy in weather and climate.*	The beginning teacher: A. Understands the elements of weather (e.g., humidity, wind speed and direction, air pressure, temperature) and the tools used for measurement. B. Compares and contrasts weather and climate. C. Analyzes weather charts and data to make weather predictions. D. Applies knowledge of how transfers of energy between Earth systems affect weather and climate. E. Analyzes how Earth's position, orientation, and surface features affect weather and climate.
Competency 018 (Solar System and the Universe): *The teacher understands the characteristics of the solar system and the universe.*	The beginning teacher: A. Understands the properties and characteristics of objects in the sky. B. Applies knowledge of the Earth–Moon–Sun system and the interactions among them (e.g., day and night, seasons, lunar phases, eclipses). C. Identifies properties of the components of the solar system.

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APPENDIX B

PS INTERVENTION LESSON: BUOYANCY

Buoyancy

OBJECTIVES:

1. The student will describe the relationship among buoyancy, mass, surface area (shape) and water displacement (i.e., be able to explain how a substance denser than water can float).
2. The student will investigate how mass affects buoyancy of a given shape in water (e.g., which boat design will carry the most cargo).
3. The student will explain Archimedes Principle, “Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object.”

TEKS 5.5 (A): classify matter based on physical properties, including mass, magnetism, physical state (solid, liquid, and gas), relative density (sinking and floating).

MATERIALS:

Aluminum foil, heavy duty
Tape
Scissors
5 containers of water for floating boats
Uniform masses (pennies or marbles, etc.)
Paper towels
Triple beam balance
Elementary balance
Metric ruler

ENGAGE

The hot air balloon activity will segue into the concept of “buoyancy”. (Discussion of a SCUBA diver’s BC can be used.)
First, using an equal arm balance show that two pieces of clay have the same mass (≈30 g). Place a 30 g ball of clay alongside of a 30 g piece of clay made into a boat shape in a 10 gallon aquarium filled with water. Observe what happens. How might you explain what happens?

EXPLORE

Management

1. Work in pairs.
2. Allow about 15 minutes for boat construction and testing of the cargo capacity.
3. Each boat will be made from a 15 cm x 15 cm piece of aluminum foil.

4. Have plenty of paper towels handy. If the cargo sinks, it will need to be dried before being reused.

Procedure

1. Give each group 15 cm x 15 cm piece of aluminum foil.
2. Make a shape using the entire piece of foil that floats. Sketch your design and also find the mass of your boat.
3. Place your boat in the water and slowly (one at a time) add masses (e.g., pennies) until it sinks.
4. Do three trials. (Take care to dry off your cargo and the inside of the hull before each trial.)

EXPLAIN

The “big ideas” from this lesson include the following:

Archimedes’ Principle states, “Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object.” More tersely: Buoyancy = weight of displaced fluid.

There are two primary forces acting on boat and cargo in this science investigation. The first force is gravity. Gravity is acting on the tin foil and pennies downward. The force of buoyancy is pushing the boat toward the surface of the water.

The gravitational force is determined by the weight of the tin foil and the weight of the pennies in the boat. The force of buoyancy is the weight of the water displaced by the boat. Your boat will continue to float as long as the force of buoyancy is greater than the force of gravity and you do not load the boat in such a way to cause it to tip over or leak.

Students should understand the vocabulary associated with the learning experiences: volume, mass, displacement, draft, gravity, fluid, and density.

1. Which of the designs carried the most cargo? Why? (e.g., optimal draft vs. area of the bottom of the hull). From the designs created by the students, which one carried the most pennies (cargo)?

2. What was the optimal shape for carrying a lot of cargo? Why? What was the shape of the boat design which carried the most pennies?

3. Was there a critical weight factor (amount of cargo – pennies)? Answers will vary.

4. What is the difference between mass and weight? Mass is how much matter something has while weight is the force generated by gravity.

5. Which variables affect buoyancy? Density of the fluid, volume of the fluid displaced, acceleration due to gravity.

6. Which variables do not affect buoyancy? Mass or density of the immersed object.

7. Density refers to the relationship between mass and volume.

8. Compare density to buoyancy. Density is the amount of matter (stuff) in a certain volume (space). It is a measure of compactness. Buoyancy deals with amount of weight compared to the density and amount of fluid displaced rather than compactness of a substance.

Density	Buoyancy
Mass	Weight (involves gravity)
It is a measure of matter per unit of volume (compactness).	Shape of the object (matter)
D = m/v	If it floats on the fluid, then it displaces a weight of fluid equal to its own weight.
If it sinks, then it has negative buoyancy.	Buoyancy is the upward force applied to a submerged object.

9. Water has a density of approximately 1 g/cm^3. Explain how a boat made of the following metals could float.

Metal	**Density g/cm^3**
Gold	19.3
Iron	7.87
Copper	8.96
Lead	11.34
Zinc	7.14
Tin	7.365

Show the DSM animation
http://www.youtube.com/watch?v=yB8c5t8Ct7I

ELABORATE

Buoyancy is important in a surprising number of fields. Designers and engineers must design boats, ships and seaplanes in a way that ensures that they remain afloat. In the case of submarines, experts developed ways to make them sink and bring them back to the surface. Many objects were developed with buoyancy in mind, such as life preservers and pontoons. Buoyancy affects many more things than most people imagine.

Additionally, buoyancy is very important in a number of water-related sports. Many swimmers know that there are easy ways to float on the surface, such as lying on a person's back or holding a full breath. Buoyancy becomes noticeable when a swimmer tries to dive to the bottom of the pool, which can take effort. Scuba divers work with many buoyancy issues, as divers must know how to float, hover and sink in the water. In fact, scuba divers often wear extra lead weights to counteract the positive buoyancy of their bodies (and wet suits [made of neoprene rubber] & dry suites [full of insulating air], in areas where the water is cold) and other gear. To compensate for the ever-increasing pressure as one dives deeper a BC (buoyancy compensator) is used to maintain neutral buoyancy.

History connection

Archimedes of Syracuse *.* (*c*. 287 BC – *c.* 212 BC) was a Greek mathematician, physicist, engineer, inventor, and astronomer. Archimedes'' Principle states that a body immersed in a fluid experiences a buoyant force equal to the weight of the fluid it displaces.

EVALUATE

Answer the following questions:

1. What is the buoyant force?
   A. The upward force that a fluid exerts on an object in the fluid.
   B. The downward force that a fluid exerts on an object in the fluid
   C. The upward force that the object exerts on a fluid when it displaces the fluid.
   D. The downward force that the object exerts on a fluid when it displaces the fluid.

2. Which of the following best describes the relationship between the buoyant force and an object in a fluid?
   A. The buoyant force is equal to the mass of the object.
   B. The buoyant force is equal to the weight of the fluid.
   C. The buoyant force is equal to the mass of the fluid that the object displaces.
   D. The buoyant force is equal to the weight of the fluid that the object displaces.

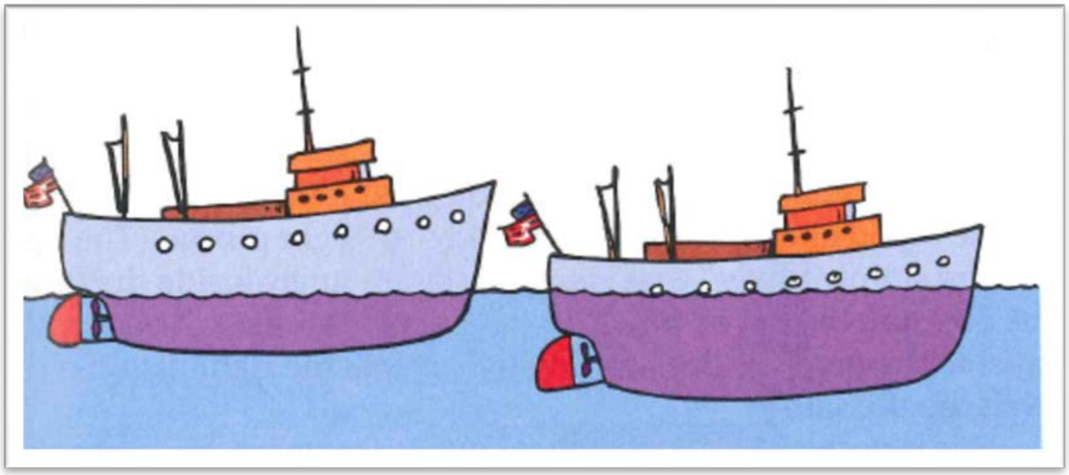
3. A helium balloon will rise if you let go of it. Which of the following is true about the balloon?
   A. There is no gravity acting on it.
   B. There is buoyant force acting on it from the air.
   C. There is no buoyant force acting on it because it is not in a fluid.
   D. It is moving, so you cannot calculate what forces are acting on it until it stops moving.

4. Explain how substances denser than water can still float.

5. Explain the difference between density and buoyancy.

6. Explain the difference between density and changes of state.

7. The picture below shows the same ship. The ship on the left is empty and the ship on the right is loaded with cargo. How does the weight of the cargo compare to the weight of the displaced water?



EVALUATE KEY

Answer the following questions:

1. What is the buoyant force?
   A. The upward force that a fluid exerts on an object in the fluid.
   B. The downward force that a fluid exerts on an object in the fluid
   C. The upward force that the object exerts on a fluid when it displaces the fluid.
   D. The downward force that the object exerts on a fluid when it displaces the fluid.

2. Which of the following best describes the relationship between the buoyant force and an object in a fluid?
   A. The buoyant force is equal to the mass of the object.
   B. The buoyant force is equal to the weight of the fluid.
   C. The buoyant force is equal to the mass of the fluid that the object displaces.
   D. The buoyant force is equal to the weight of the fluid that the object displaces.

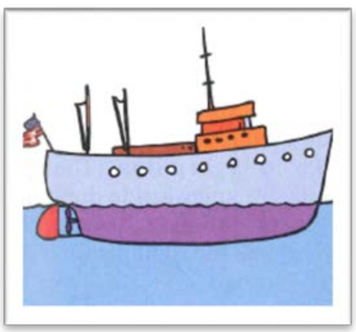
3. A helium balloon will rise if you let go of it. Which of the following is true about the balloon?
   A. There is no gravity acting on it.

B. There is buoyant force acting on it from the air.
C. There is no buoyant force acting on it because it is not in a fluid.
D. It is moving, so you cannot calculate what forces are acting on it until it stops moving.

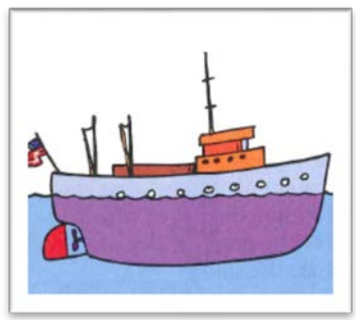
4. Explain how substances denser than water can still float on the surface of a fluid.
The amount of weight displaced is equal to the weight of the fluid.

8. Explain the difference between density and buoyancy.

9. The picture below shows the same ship. The ship on the left is empty and the ship on the right is loaded with cargo.
   a. Which ship displaces more water? B
   b. Which one has more cargo? B
   c. Which one weighs more? B
   d. Which one has the greater buoyant force? B
   e. How does the weight of the ship compare to the weight of the displaced water? Both A and B are equal



A



B

Activity 2 (0ptional)

Another version of Archimedes' Principle states that a body immersed in a liquid, wholly or partly, loses some weight. The loss of weight is equal to the weight of the liquid displaced by the body.

Take a spring balance, a piece of stone (or other submersible object), a measuring cylinder and water. Measure the weight of stone in air by tying the string around in a loop, and hanging it from the spring balance. Take water in a measuring cylinder and note its volume level. Then dip the stone in the water while it is still hanging from the spring balance. You will see that the stone is weighing less!!

APPENDIX C

PS INTERVENTION LESSON: DENSITY

Density of Matter

OBJECTIVES:

1. The student will be able to calculate density.
2. The student will use density to classify substances.
3. The student will describe the relationship between mass and volume with regard to density.
4. The student will explain why density is a physical property.
5. The student will explain why less dense fluids rise above fluids with greater density

TEKS 6.6 (B): Calculate density to identify an unknown substance.

MATERIALS:

Bowling balls (2.7 kg. and 4.5 kg.)	Tea bags	Glazed Donuts
Density blocks	Graduated cylinder	50 g. Powdered sugar
Medicine cups	Test tube	50 g. Salt
Test tubes	Red food coloring	50 g. Flour
Triple beam balance	Alcohol (wintergreen)	Glazed Donut holes
9” Balloons	Water colored red	Can of Coke®
Two Paper bags (lunch size)	Brown Karo® syrup	Can of Diet Coke®
Metric ruler	Blue Dawn detergent	Italian salad dressing

PRETEST

1. Write down as many terms associated with “density of matter” as you can think of.
2. Draw a concept map using all the identified terms you describe for the process of density.

ENGAGE

Teacher Setup: Fill one bag with donut holes and the other bag with glazed donuts. An alternative set up is to fill 9” balloons with powdered sugar, salt, and flour.

1. Examine the bags (or balloons) shown to you by your instructor. What can be said about the mass of each paper bag (balloon) using only observations?
2. How do we know the volume of the paper bag (or balloon)?
3. Make a prediction about the mass of the paper bag (balloon).
4. Use the triple beam balance to determine the mass for each bag (or balloon) and its contents. Which bag has more mass?
5. Did you discover a discrepant event during your investigation with the paper bags (balloons)?

Learning Experience 1

Examine the blocks given to you by the teacher. Measure the blocks and determine the volume for each block.
Use the triple beam balance to determine the mass for each paper bag and its contents. Arrange the blocks in order of magnitude from lightest to heaviest.

	Block #1	Block #2	Block #3	Block #4	Block #5
Mass					
Volume					
Density (d = m/v)					

Table 1

1. What can be said about the blocks?

2. What can be said about the blocks? How can you use your knowledge about molecules to explain why the blocks have different masses?

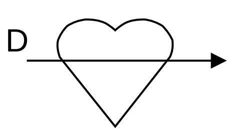
3. Use the formula for density (d = m/v) to calculate the density for each of the five substances in Table 1.

4. If one of the density blocks is cut in half, then what is the density of the two smaller blocks?

5. If the copper density block is doubled, then what is the density of the larger copper block?

6. Given a change in the volume and mass of the same substance, what is the effect on density?

A good way to remember the formula for density is to remember the statement, “I love density.” The top of the heart looks like the letter “m” for “mass” and the bottom of the heart looks like the letter “v” for “volume”. The arrow makes the division line for mass divided by volume.



Learning Experience 2

Place each block in a graduated cylinder with 50 ml of water. Record the amount of water displaced by the block.

	Oak	Aluminum	Copper	Steel	Brass
Mass					
Volume of H_2O displaced by block					
Density					

Table 2.

1. How does the amount of water displaced by the block compare with the value you recorded in Table 1?
2. Describe two methods which can be used to determine the volume of a substance.
3. How does the density for each substance in Table 1 compare to the density for the same substance in Table 2?

Learning Experience 3

Procedure:

1. Label five medicine cups A-E. Fill each cup 1/2 full.
2. Fill cup A with blue dawn dish detergent.
3. Fill cup B with oil.
4. Fill cup C with water tinted with red food coloring.
5. Fill cup D with brown Karo® syrup.
6. Fill cup E with the alcohol (wintergreen).

Sequentially pour each substance into a large test tube (about 60 ml). Add each liquid slowly as you decant the liquid down the side of the test tube.

1. Draw and color a picture of what you see. Be sure to include labels.

2. Explain why the substances layered as they did? Make inferences based on your observations.

Learning Experience 4

Go to the following website, and view the hot-air balloon simulation.
http://www.eduplace.com/science/hmsc/4/e/simulation/simcontent_4e.shtml

1. Compare the air temperature inside and outside the balloon when the balloon is in the air. Why does a hot air balloon float?

2. Why does the hot air balloon remain level in the air?

3. Why does the hot air balloon come back to the landing pad?

EXPLAIN

The "big ideas" from this lesson include the following:

Measure of compactness – pack more mass into same volume (suitcase)
Density is a physical property
Less dense objects rise above objects with greater density
Denser objects will fall below objects with less density.

Familiarity with misconceptions about density will help teachers address learning challenges and facilitate acquisition of knowledge/processes which hold a scientific view.

Density Misconceptions

Myth	Scientific Explanation
Density is the same as thickness.	Density does not necessarily mean thickness. That is, the terms are not equivalent. For example, a geode may appear to be thick, but inside it is hollow. In the crust of the Earth, some rocks are denser than others. The continental crust is mainly composed of granite (~ 2.6 density) and basalt (~ 3.0 density) which has different densities. That means, a 10 kilometer thick layer of basalt is denser than a 10 kilometer thick layer of granite.

Larger objects are denser than smaller objects.	Larger objects are not necessarily denser. For example, a pumice stone floats, while a smaller rock (such as a pebble) will sink.
Weight and density are the same thing.	Density is the relationship between mass and volume.
Mass/volume/weight/heaviness/size are equivalent.	Each of these terms can have a different meaning.
Mass and density are the same thing	Mass is the amount of matter in an object and can be found by using any type of balance such as a triple beam balance. The mass of an object does not change unless you add to it or take away from it. Changing an object's shape or compressing it will not change the mass unless matter is gained or lost in the process.
Volume and density are the same thing.	Volume is the amount of space an object takes up. It may be found by using a graduated cylinder for liquids or for solids if the water displacement method is used. If the object is a regular solid such as a square or rectangle, the following formula may be used to calculate its volume: length x width x height.
Weight and mass are equivalent.	For example, the gravity of the moon is 1/6 of what it is on Earth so people have different weights on the moon and the Earth.
Density only refers to solid objects and water.	Density is the relationship between mass and volume of substances in all states: solid, liquid, and gas.
Liquids with high viscosity also have high density.	Temperature affects viscosity. For example, when syrup is heated to near boiling, it becomes less viscous.

The density of a substance changes when the volume or mass changes.	Density is a property of a substance. Doubling or reducing the mass of a copper sample, will not change the density of the sample. Changing the volume of water will not change the density of water.

Students should understand the vocabulary associated with the learning experiences: volume, mass, immiscible, miscible, viscous, atoms, molecules, and density.

Immiscible/miscible refers to whether or not two substances will form a homogenous or heterogeneous mixture. For example, oil and water are immiscible, that is they do not dissolve. Water molecules have strong hydrogen bonds. Oil molecules are bonded to one another by London forces or sometimes dispersion forces. Large oil molecules tend to clump together. The attraction of oil to a water molecule is weak compared to the oil to oil attraction.

Each of the five learning experiences should be debriefed.

KEY TO LEARNING EXPERIENCES 1-4

Teacher Setup**:** Fill one bag with donut holes and the other bag with glazed donuts. An alternative set up is to fill 9" balloons with powdered sugar, salt, and flour.

1. Examine the bags (or balloons) shown to you by your instructor. What can be said about the mass of each paper bag (balloon) using only observations? Using observation only, it is not possible to determine how heavy the bag is.

2. How do we know the volume of the paper bag (or balloon)? The formula for calculating volume of a rectangular paper bag is L x W x H.

3. Make a prediction about the mass of the paper bag (balloon). The students might predict the bags (balloons) are the same or they are different.

4. Use the triple beam balance to determine the mass for each paper bag (or balloon) and its contents. Which bag has more mass? The bag with donut holes is heavier. There is a difference between mass and weight. For example, the gravity of the moon is 1/6 of what it is on Earth.

5. Did you discover a discrepant event during your investigation with the paper bags (balloons)? The bags look similar and have the same volume, but have different weights. Why? The donut holes are more compact than the regular glazed donuts.

Learning Experience 1

Examine the blocks given to you by the teacher. Measure the blocks and determine the volume for each block.
Use the triple beam balance to determine the mass for each paper bag and its contents.
Arrange the blocks in order of magnitude from lightest to heaviest.

	Block #1	Block #2	Block #3	Block #4	Block #5
Mass					
Volume					
Density (d = m/v)					

Table 1

1. What can be said about the blocks? The blocks look similar and have the same volume, but have different masses.

2. What can be said about the blocks? The blocks look similar and have the same volume, but have different masses. How can you use your knowledge about molecules to explain why the blocks have different masses? The blocks that are heavier have molecules whose lattice arrangements are closer together. We call this degree of compactness of a substance density. Density describes the relationship between mass and volume. The formula for density is d = m/v. Density is the mass per unit of volume.

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A good way to help students remember the formula is the statement, "I love density." The top of the heart looks like the letter "m" for "mass" and the bottom of the heart looks like the letter "v" for "volume". The arrow makes the division line for mass divided by volume.

3. Use the formula for density (d = m/v) to calculate the density for each of the five substances in Table 1.

4. If one of the density blocks is cut in half, then what is the density of the two smaller blocks? The density is the same.

5. If the mass of the copper density blocks is doubled, then what is the density of the larger mass of copper? The density is the same.

6. Given a proportional change in the volume and mass of the same substance, what is the effect on density? The density is the same.

Learning Experience 2

Place each block in a graduated cylinder with 50 ml of water. Record the amount of water displaced by the block.

	Oak	Aluminum	Copper	Steel	Brass
Mass					
Volume of H_2O displaced by block					
Density					

Table 2.

How does the amount of water displaced by the block compare with the value you recorded in Table 1? The volumes are the same.

Describe two methods which can be used to determine the volume of a substance. Measurement and water displacement.

How does the density for each substance in Table 1 compare to the density for the same substance in Table 2? The densities should be the same.

APPENDIX D

PS INTERVENTION LESSON: DISSOLVING

Objective: The student will be able to demonstrate the different between soluble and insoluble substances based on physical properties.

TEKS 5.5C: demonstrate that some mixtures maintain physical properties of their ingredients such as iron filing and fine gravel

Materials:

- Microscope
- Scale
- Beakers
- Salt
- Sugar
- Fine gravel
- Microscope slides
- Iron filings
- Stirrers
- Hot plates (4)
- Ice
- Timers
    -

PRETEST

1. Write down as many terms associated with “dissolving” as you can think of.
2. Draw a concept map using all the identified terms you describe for the process of dissolving.
3. Briefly describe the process of dissolving.
    -

ENGAGE

Show the video clip about gold dissolving in mercury. Start at 53 seconds and play to the end of the clip. Turn OFF the volume.

http://www.youtube.com/watch?v=gKxCw889qck

EXPLORE

- What is the first step in the Scientific Method? *Observation*
- Look at the four substances under a dissecting microscope.
  - salt, sugar, fine gravel, and iron filings.
  - On your paper, make observations using your five senses, minus taste, about each of the substances (Table 1).
  - Now that you have observed these substances, use Table 1 to make predictions about whether or not you think they will dissolve in water. (Hypothesis)
    - Remember to use your “if, then” statements.
    - Ex. “If we mix ____ with water, then ____ will/will not dissolve.”
  - What will be the variables in this experiment? Controls? *Salt, sugar, fine gravel, iron filings; amount of water, time of stirring, temperature of water, amount of each substance*
  - What is the independent variable? *type of substance*
  - What is the dependent variable? *whether the substance dissolves or not.*
- Now that you have made your observations and hypothesis, let’s conduct the experiment.
- In your groups (assigned by teacher), follow the direction sheet at your table (attached).
- Remember your safe practices!
- Teacher walks around monitoring, observing, and helping students.

DIRECTIONS:

Examine sugar, salt, iron filings, and fine gravel under a microscope. How does each substance look? That is, what is the basic shape of the particle?
Question #1: Does stirring increase dissolving?
Think about how to design a “fair test” to answer this question. What is used as a stirring instrument? Define stir. How rapid is the stirring process?
Question #2: How much solid can be dissolved in 100 ml of room temperature water?

1. Start with 20 grams of each substance.
2. Add 20 g of fine gravel to 200 ml of water. Continuing adding 20 g of the solid to the water until the solute does not dissolve.
3. Add 20 g of sugar to 200 ml of water in a beaker. Continuing adding 20 g of the solid to the water until the solute does not dissolve.

4. Add 20 g of sugar to 200 ml of water in a beaker. Continuing adding 20 g of the solid to the water until the solute does not dissolve.

5. Add 20 g of oil to 200 ml of water in a beaker. Continuing adding 20 g of the solid to the water until the solute does not dissolve.

6. Is there a limit to how much solid can be dissolved in a given amount of water? Why?

Table 1

Will It Dissolve?							
Will it Dissolve? Water + ?	Observation of physical properties	Predict – Will it dissolve?	If…then hypothesis statement	Did it dissolve?	# grams dissolved in room temperature water (____°)	# grams dissolved in cold water (____°)	# grams dissolved in boiling water (____°)
Fine gravel							
Sugar							
Salt							
Oil							

EXPLAIN

- After the students record their results on the table on the chalk board, the teacher will conduct a whole class discussion:
  - o What did we find out about the solubility of fine gravel? Sugar? Salt? Iron filings?
    - *Fine gravel – insoluble*
    - *Iron filings – insoluble*
    - *Salt – soluble*
    - *Sugar - soluble*
  - o Did any group discover that salt and sugar were insoluble? No. Tell us about what you discovered. The solutes, salt and sugar were soluble in the solvent, water. That is they dissolve.
  - o Did any group discover that fine gravel and iron filings are soluble? No. Tell us about what you discovered. The solutes, gravel and iron filings were insoluble in the solvent, water. That is they did not dissolve. The water in the iron filings was cloudy, but the suspension in the water settled out over time.

- What are some other substances that you think are soluble in water? Coffee, tea, Kool-Aid mix. Insoluble? Sand, gravel, marble, granite, rubber, plastic.
    - *Various answers*
- If you wanted to test the solubility of a substance in water, how would you go about doing so?
    - *Mix the substance with the water*
    - *If the substance settles out, the substance is insoluble.*
    - Misconceptions – (
        - particles change from solid to liquid [dissolving is not a phase change]
        - the covalent bonds of molecules break to enable the process of dissolving [intermolecular forces separate whole molecules instead]
        - the particles break down instead of the molecules separate on the molecular level [this is a concrete macro view instead of micro view at the molecular level about dissolving]
        - the solute disappears [the solute is still there and the process is reversible for example through evaporation]
        - the particles melt because of heat [physical change misconception]
- Why is this information important?
        - *Cooking – This is important in cooking candy. For example, if there is too much sugar added to fudge, then it will not dissolve and the fudge will taste grainy because of the sugar crystals. Also, at certain temperatures, the dissolved sugar will begin to crystallize causing a granular texture to the candy.*
        - *Planting – In fertilization of the lawn, if salts do not dissolve, then the lawn will not receive the nutrients it needs.*
        - *Cleaning – Dissolving dirt on clothing with detergent, dissolving dishwashing powder to wash dishes in the dishwasher, and using drain cleaner to unclog pipes in your home.*
- “sol” is the root word in both soluble and dissolve. “-able” means capable of being, and “in-“ means not. Therefore, soluble is able to dissolve, and Insoluble is not able to dissolve.

o Vocabulary to teach: molecule, soluble, insoluble, saturate, supersaturate, solute, solvent, and solution

sugar dissolving in water
http://www.inquiryinaction.org/chemistryreview/dissolving/
salt dissolving in water
http://www.northland.cc.mn.us/biology/biology1111/animations/dissolve.html
DEBRIEFING ACTIVITY:

-

1. Did stirring have an effect on the solubility *o*f fine gravel or iron filings? *No*

2. Did stirring have an effect on the solubility *o*f sugar or salt in water? *Yes, the stirring facilitated the separation of the sugar molecules in water.*

3. What did you think would happen to the solubility of salt/sugar/fine gravel/iron filings when mixed with room temperature water, hot water or cold water? *Hot - fine gravel/iron filings will remain insoluble; sugar/salt will dissolve more quickly; Cold – fine gravel/iron filings will remain insoluble; sugar/salt will dissolve more slowly.*

4. Why do you think that? *Various answers*

   o If the salt and sugar solutions are heated, are the particles (atoms or molecules) farther apart or closer together? Why? *The energy is increased when a substance is heated, so the molecules move more quickly, spreading apart. The heat causes the molecules to move faster so the solvent and solute particles bump into one another more and this causes them to break up more quickly (facilitates dissolving in polar substances).*

   o If a substance is cooled, are the particles farther apart or closer together? Why? *The energy is decreased when a substance is cooled (heat is lost), so the molecules move more slowly, thus they do not bump into one another or break up as much.*

5. Did the temperature change have an effect on the solubility *o*f fine gravel or iron filings? *No*

Learning Experience 3

Procedure:

1. Label five medicine cups A-E. Fill each cup ½ full.
2. Fill cup A with blue dawn dish detergent.
3. Fill cup B with oil.
4. Fill cup C with water tinted with red food coloring.
5. Fill cup D with brown Karo® syrup. Discrepant event

6. Fill cup E with the alcohol (wintergreen). Discrepant event

Sequentially pour each substance into a large test tube (about 60 ml). Add each liquid slowly as you decant the liquid down the side of the test tube.

1. Draw and color a picture of what you see. Be sure to include labels. Layers from top to bottom: green alcohol, white oil, red water, blue Dawn® detergent , brown Karo® syrup.

2. Explain why the substances layered as they did? Make inferences based on your observations. There are two explanations for why the liquids stay separated in the test tube. One explanation is that each liquid has its own density and some liquids have a lower density number than other substances. The other explanation is that some of the liquids are immiscible liquids. That is they do not mix with each other (oil and water).

Remembering to remember: Use the following rap. What is an observation? Using the senses to get information (clap) observation. Explain an observation (clap clap) inference.

Learning Experience 4

Go to the following website, and view the hot-air balloon simulation.
http://www.eduplace.com/science/hmsc/4/e/simulation/simcontent_4e.shtml

1. Compare the air temperature inside and outside the balloon when the balloon is in the air. The temperature inside the balloon is greater. Why does a hot air balloon float? The density of the air outside the balloon is greater than the density of the air inside the balloon. As shown in the density layering lab, substances which are less dense will layer above substances which have a greater density.

2. Why does the hot air balloon remain level in the air? When the hot air balloon is level in the air, then the density of the air inside the balloon is equal to the density of the air outside the balloon.

3. Why does the hot air balloon come back to the landing pad? When the density of the air inside the balloon is greater than the density of the air outside the balloon, then it will come back to the Earth.

4. Using your knowledge about how hot air balloons float, explain how does density allows water to recycle through the water cycle? When water is heated by the Sun, it changes from a liquid to gas state and rises into the air. This is called evaporation. When water cools in the atmosphere, then it begins to condense

and fall back to the Earth. Water is the only substances on Earth that naturally and simultaneously exists as a solid, liquid, and gas.

State of Matter	Temperature °C	Density (Pure Water g/cm^3)
Solid	0	0.9150
Liquid	+4	0.9990
Gas	100	0.0006

http://www.simetric.co.uk/si_water.htm

ELABORATE

Oil film on a puddle of water or oil floating in the ocean after the BP oil spill is an example of how density relates to everyday life. The oil is less dense than the water, thus it tends to layer on top of the water.

Bone density is a measure of the amount of matter in bones. It is used as an indicator or osteoporosis and risk for fractures.
As women get older (+65) they are at increased risk for osteoporosis. Also, women who are estrogen deficient or individuals who receive long-term steroid therapy have increased risk.

When designing pipe systems, the density of a fluid that moves through the pipes and determines how powerful the pump will need to be.

Hot air balloons float because the hot air that fills the balloon is lighter and less dense than the cool air around the balloon. This can also be shown using a teabag.

Salad dressing layers such as oil and vinegar dressing or Italian dressing eventually settle back to the same order after being shaken up.

Using your knowledge about how hot air balloons float, explain how density allows water to recycle through the water cycle.

EVALUATE

Answer the following questions:

1. What is the formula for calculating density?

2. A student is given an unknown substance. The student determines that the mass of the substance is 68g and the volume is 75.55 cm^3. Use the following chart to determine the unknown substance.

Density for Common Substances

Substance	Density g/cm^3
Acetone	0.784
Gasoline	0.700
Kerosene	0.900
Methanol	0.786

3. Calculate the density for each of the following substances.

Substance	Mass (g)	Volume (cm$^{3)}$	Density
Water	10.0	10.0	
Block of wood	19.9	34.8	
Rock	5.7	2.0	

4. Two liquids have the same volume, but one has more particles packed in the volume. Using the concept of density, provide an explanation.

5. Two liquids have the same volume, but one liquid has more mass. Does this mean one with greater mass is denser?

6. What is the relationship between mass volume and density?
   -

7. Does doubling the amount of a substance change its density if the volume increases at the same rate? Why or why not?

8. Explain the Coke® and Diet Coke® can demonstration. *Demo by teacher.*

9. Explain in your own words the concept of density (go beyond just listing the density equation).
   -

10. Explain the difference between density and weight.

EVALUATE KEY

Answer the following questions:

1. What is the formula for calculating density? d = m/v

2. A student is given an unknown substance. The student determines that the mass of the substance is 68g and the volume is 75.55 cm^3. Use the following chart to determine the unknown substance.

Density for Common Substances

Substance	Density g/cm^3
Acetone	0.784
Gasoline	0.700
Kerosene	0.900
Methanol	0.786

Using the density formula, the density of the substance is .900. The substance is kerosene.

3. Calculate the density for each of the following substances.

Substance	Mass (g)	Volume (cm^3)	Density
Water	10.0	10.0	1.00
Block of wood	19.9	34.8	0.57
Rock	5.7	2.0	2.85

4. Two liquids have the same volume, but one has more particles packed in the volume. Using the concept of density, provide an explanation. Density if the relationship between mass and volume of a substance. Using the density formula, a change in mass (more particles packed in the volume) would cause the density for the two liquids to be different.

5. Two liquids have the same volume, but one liquid has more mass. Does this mean one with greater mass is denser? Yes. The only way for the liquid to have more mass is to have more particles packed in the same volume.

6. What is the relationship between mass volume and density? With regard to density, if mass and volume increase proportionally, then the density stays the same. If the mass or the volume changes, then the density will change.

-

7. Does doubling the amount of a substance change its density if the volume increases at the same rate? No. Why or why not? Density is the relationship between mass and volume so if mass and volume proportionally increase, according to the density formula, the density stays the same.

8. Explain the Coke® and Diet Coke® can demonstration. *Demo by teacher: A can of Coke® and a can of Diet Coke® are dropped into a 10 gallon aquarium. The can of Diet Coke® floats while the can of Coke® sinks. Explain why this happens.*

The density of the Diet Coke® is less than the Coke®. Both have the same volume so the mass must be different. This could be verified by using a triple beam balance and taking the mass of each can of soda.

9. Explain the relationship between density and change of state. When liquid water freezes it becomes less dense (volume is more compared to mass). In general substances become less dense as they move from solid to liquid to gas.

10. Explain in your own words he concept of density (go beyond just listing the density equation). Density is a physical property of matter (fluids and solids). It includes units of measurements (g/cm^3). It is a relationship between mass and volume. Mass is not equal to weight (weight deals with sinking and floating). Density is not a change of state. Density does not change with quantity.

11. Explain the difference between density and weight. When liquid water freezes it becomes less dense (volume is more compared to mass). In general substances become less dense as they move from solid to liquid to gas.

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