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Evaluating the Effectiveness of Project ReCharge:
A STEM Based Energy Efficiency Curriculum

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Abstract

This research evaluates the effectiveness of Project ReCharge, an energy efficiency, STEM curriculum designed for middle and high school students. The project includes a five-unit curriculum, and monthly professional development spanning a year. The project was implemented in ten schools over three years. Four areas were explored in the study including (1) changes to student content knowledge, (2) changes to student attitudes towards STEM subjects and careers, (3) changes to teacher self-efficacy and beliefs, and (4) changes to teacher content knowledge. A content test for teachers and students, the STEM Semantics Survey, and STEBI-A were used to collect data on 4123 students and 47 teachers. Data were collected in a quasi-experimental design utilizing parametric and nonparametric techniques. Analyses suggest student content knowledge increased significantly from pretest to posttest for all years (Pretest: $M = 11.38$, $SD = 4.97$, Posttest: $M = 16.67$, $SD = 5.83$, $t = 45.05$, $p < 0.001$, $d = 0.98$). Increases to student attitudes in STEM varied by year and grade, but overall increases were found in science ($N = 2362$, $z = -2.618$, $p = 0.030$, $\eta^2 = 0.002$), and math attitudes ($N = 2348$, $z = -2.280$, $p = 0.023$, $\eta^2 = 0.002$). High school students tended to show more increased attitudes in more subject areas than middle school students. No changes to teacher self-efficacy and beliefs were found, and increases to teacher content knowledge only occurred in the third year ($N = 22$, $x^2 = 5.158$; $p = 0.076$, $\eta^2 = 0.319$).

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Chapter One: Introduction

Schools are expected to engage students in real-world, problem-solving experiences; those that mirror real-world professions, and develop twenty-first century skills (Prettyman, Ward, Jauk, & Awad, 2012). The integration of science, technology, engineering, and mathematics (STEM) education into schools promotes these skills (Becker & Park, 2011). Society today is profoundly influenced by scientific discoveries, requiring more students to develop scientific literacy. Thus, having the scientific knowledge and understanding to enhance technologies and engineering, and meeting the ever-changing needs of the population (National Research Council, 2000). It is no longer sufficient that education simply focus on intellectual growth through teaching facts of independent disciplines in isolated silos, but instead should transcend traditional structures of teaching the independent disciplines of science, technology, engineering, to a more integrated approach. One that develops scientific literacy and values the application of knowledge required for students to make informed decisions about the world (Bybee, 2013).

Background Literature

Establishing a STEM focus in kindergarten through twelfth grades can help to engage students in STEM disciplines, which in turn can lead to students pursuing degrees in these disciplines and ultimately choosing careers in STEM (Buckley, 2009). Too few workers in the United States have backgrounds in STEM fields, creating a need for a new approach to teaching these disciplines in kindergarten through twelfth grade. Of particular concern are green energy jobs and careers. As defined by the Bureau of Labor Statistics (BLS) green jobs “produce goods and provide services that benefit the environment or conserve natural resources" (Bureau of Labor Statistics, 2016). The BLS received funding in 2010 to collect data on green jobs reporting 3.4 million green jobs, equating to only 2.6 percent of jobs in the United States in 2011 (Bureau of Labor Statistics, 2016). However, the U.S. Department of Energy reported a growth of nearly eighteen percent in the green energy sector between 2015 and 2016, and it is predicted these jobs will grow between nine and eleven percent by the end of 2017 (Environmental and Energy Study Institute, 2017), placing additional pressures to educate and to expand the STEM workforce in these fields.

Encouraging more students to enroll in STEM classes, graduate with STEM degrees, and pursue careers in STEM fields, will allow the United States to compete in a global marketplace, and continue to excel with the scientific and technical expertise necessary for success in today's economy (Buckley, 2009; Community for Advancing Discovery Research in Education, 2013). Fields specifically at risk in the United States include the physical sciences and engineering, with declines in the quantity of doctorates awarded in these areas in the past two decades (Tai, Liu, Maltese, & Fan, 2006). Research has suggested students who enter eighth grade with expectations of obtaining degrees and pursuing careers in STEM related fields are twice as likely to graduate with degrees from and obtain careers in their chosen STEM field (Tai et al., 2006) increasing the importance of providing quality, inquiry-based STEM programs in the elementary and middle school grades.

Incorporating quality STEM programs in school is the first step to providing access to and experience with STEM phenomena. Beginning in the elementary grades, students' exposure to STEM subjects and careers through highly engaging, meaningful, quality curricula is paramount to develop positive attitudes and motivation towards these careers, thus generating a desire to continue learning the practices of STEM subjects and careers (Ozel, Caglak, & Erdogan, 2013). Correlations between affective factors and achievement increase as students progress through school, placing additional pressures to develop positive attitudes towards STEM in the middle and high school grades (Ozel et al., 2013).

Studies show students who are engaged in integrated STEM classes and programs tend to have more positive attitudes towards STEM disciplines and take more advanced science and math courses in high school and four-year colleges (DeJarnette 2012; Tseng, Chang, Lou, & Chen, 2013). The importance of positive attitudes in STEM subjects has been researched and suggest students have higher academic achievement and are more likely to choose a career in a STEM field after they graduate (Newell, Tharp, Moreno, Zientek, & Vogt, 2015; Ozel et al., 2013; Tai et al., 2006). Furthermore, students with more positive attitudes become invested in real world problems and become the creators of knowledge, rather than just consumers of it (Prettyman et al., 2012). Additional studies have also concluded that students who are engaged in the integrative approaches of STEM education have greater achievement of individual STEM disciplines when compared to their counterparts who did not receive integrated STEM approaches (Becker & Park, 2011; Scott 2012).

With the goals of increasing access to integrated STEM programs, increasing interests in STEM subjects and careers, and increasing content knowledge surrounding energy and energy efficiency, this research explores the overall effectiveness of Project ReCharge. This cutting edge, energy curriculum has been designed for middle and high school students to explore real-time energy consumption, utilizing data monitoring hardware and software placed within a school site. Meeting the needs outlined by the National Research Council for effective STEM education, including: 1) increase the number of students who pursue STEM careers, 2) expand the STEM capable workforce for women and minorities, and 3) increase STEM literacy for all students (NRC, 2011; p. 14), Project ReCharge has been developed as an integrated STEM curriculum to engage minority populations in inquiry techniques while developing STEM literacy in energy and energy efficiency. The current study researches the implementation of Project ReCharge with at-risk populations, specifically schools with a low-income and high minority population, allowing access to STEM phenomena for minority and female students.

The major goals of Project ReCharge included installing and preparing ten middle and high school sites with energy monitoring hardware, and engaging over 3,000 middle and high school students in the energy curriculum. A total of forty-seven middle and high school teachers were provided professional development surrounding the energy efficiency curriculum and the Next Generation Science Standards (NGSS Lead States, 2013), as well as additional support of inquiry practices. The project and goals were met over a three-year period.

The curriculum includes five units, providing opportunities to build conceptual understanding through hands-on inquiry approaches, all aligned to the Next Generation Science Standards (NGSS Lead States, 2013). Units one through three support development of background knowledge about energy, electrical generation through renewable sources, and how building elements use energy including lighting and appliances, insulation, and heating. Unit four includes tasks for students to collect data from various appliances, and other electrical loads to analyze how much energy each uses. Data is collected through non-intrusive appliance load monitoring (NIALM) hardware installed directly at the school site. An online student dashboard allows students to visually see how much energy is used when they plug in different appliances or turn on different light switches. In unit five students collect and analyze energy data from unit four to make proposals about behavior or appliance changes that would save the school ten percent of their monthly energy bill.

Utilizing pretest and posttest data collected from students before and after they completed the first three units of the curriculum, significant differences have been found in student content knowledge in the area of energy and energy efficiency for all years of the grant and for both middle and high school student groups. In addition to increases in student content knowledge, increases to student attitudes in various STEM subjects and careers have also been found between pretest and posttest with students who are participating in the project ReCharge curriculum. Overall increases in science and engineering were found after the three years of the grant, and increases to high school attitudes towards STEM and STEM careers were also found.

In addition to a rigorous curriculum, a tenacious professional development plan adhering to current research is necessary (NRC, 2011). Research suggests effective professional development should have five characteristics: (1) content focus, (2) active learning, (3) coherence, (4) duration, and (5) collective participation (Desimone, 2009). These characteristics are considered a consensus model and tend to be included in professional development for science education as well (NRC, 2015). However, current research has gone beyond these five attributes in science education professional development to include additional considerations shown to increase changes in teacher learning outcomes, student learning outcomes, and the relationships among various opportunities for teachers to learn. These additional components include "[1] Teachers' science content learning is intertwined with pedagogical activities… [2] Teachers are engaged in analysis of student learning and science teaching using artifacts of practice… [3] There is a focus on specific targeted teaching strategies, [4] Teachers are given opportunities to reflect on and grapple with challenges to their current practice, [5] Learning is scaffolded by knowledgeable, professional development leaders, [6] Analytical tools support collaborative, focused, and deep analysis of science teaching, student learning, and science content. (National Academy of Sciences, 2015; 134-135).

Project ReCharge professional development meets all five characteristics of the consensus model (Desimone, 2009) with an intensive summer institute for participating teachers, implementation specialists, and administrators. Monthly professional development sessions focused on curriculum implementation and increasing teacher content knowledge, and providing current research on inquiry teaching practices and content standards. Additionally, specific attention was paid to connecting learning content to the pedagogy of STEM and inquiry. A focus on inquiry strategies throughout the curriculum and professional development was explicitly employed to encourage changes to classroom practices. Teachers from each year of implementation received monthly professional development from August through May. Throughout each yearly professional development cycle, local professionals from energy and power companies were brought in to give insight into real world applications. However, not all of the additional criteria for effective professional development for science, as outlined by the National Academy of Sciences (2015) were met with this project. Teachers were not able to analyze student data or reflect on their practices and struggles. Nor was any analysis of science teaching or student learning conducted.

The potential to create positive changes in science teachers' self-efficacy and outcome expectancies in science education exists if professional development utilized trained professionals providing the professional development. A lack of understanding of in how to provide professional development after year one left teacher participants with no reason to change their instructional methods, allowing for teachers to revert back to one dimensional teaching. Providing a structure to analyze their own teaching abilities and reconcile them with the three dimensions of the NGSS would allow teachers to make changes to their instruction and begin to shift away from traditional didactic approaches.

The combination of a quality STEM program focused on energy and energy efficiency and its implementation in high-needs middle and high schools, with research-based professional development practices could lead to greater interest in STEM subjects and careers. This combination could ultimately lead to more students pursuing higher education courses and ultimately careers in green energy or related STEM areas. Determining if a program is of high-quality through research based analyses is necessary prior to mass implementation of a program.

Problem Statement

Currently, the United States suffers from a lack of rigorous kindergarten through twelfth grade STEM programs (Sahin & Top, 2015). Inquiry based, STEM programs aligned to the NGSS are beginning to appear across the country (Mahoney, 2010).

However, due to a lack of research it remains unclear how effective they are at increasing interest in STEM and preparing students for futures in STEM careers (NRC, 2014). Additional barriers include the absence of adequate professional development STEM education, and true standards-aligned curriculum (Sahin & Top, 2015). With increasing literature supporting correlations between student interest in STEM subjects and their choice to pursue STEM degrees and careers, it is important to consider the affective domain when evaluating programs (Berlin & White, 2012; Mahoney, 2010). Additionally, research suggests a correlation between student achievement and teachers' professional development, requiring effective professional development aligned to current research to be conducted (Darling-Hammond, 2000; Whitworth & Chiu, 2015).

One crucial aspect to increasing STEM literacy in the United States is to put in place consistent systems of program assessment to determine the effectiveness of the inquiry programs to which students are exposed (NRC, 2013; Scott, 2012). Evaluations of programs should include changes to student content knowledge, interest in STEM subjects (NRC, 2013), and shifts in inquiry approaches to be more reflective of professionals in the field. Currently, sufficient data for STEM programs aligned to the NGSS are lacking. Take into account the teacher implementing the curriculum as another requirement of an effective program and the results are even more limited. The current lack of research surrounding newly created STEM programs and their ability to increase student content knowledge and interest in STEM subjects and careers has created a gap in the literature and a need for further research.

Purpose of the Study

The purpose of this quantitative, quasi-experimental study (Creswell, 2014) is to determine the effectiveness of Project ReCharge in relation to student content knowledge in the area of energy, student interest in STEM fields and careers, and changes in teacher inquiry practices and self-efficacy. Quantitative data were collected to develop a comprehensive analysis of the project. The effectiveness of the program was determined by analyzing quantitative data collected on middle and high school students in both content and interest in STEM subjects and careers utilizing a pretest/posttest design. A multiple-choice content test was created and refined for validity and reliability to determine changes in content knowledge. The STEM Semantics Survey (Tyler-Wood, Knezek, & Christensen, 2010) was utilized to determine changes in students' interest in STEM subjects and careers and was also administered as a pretest and posttest.

Effects of professional development and program implementation were determined by collecting quantitative data from participating teachers as well. Teachers were given the student content test, and the Science Teachers Efficacy and Beliefs Instrument (STEBI-A; Riggs & Enochs, 1990) to determine changes to self-efficacy as a result of participating in the professional development and implementing the program in their classrooms. In addition to the quantitative data, focus groups were utilized as well as surveys to help the formative development of the project and used to inform the statistical results. Teachers in the first year of implementation were given the assessments in a pretest/posttest design, whereas teacher participants from years two and three were given three administrations of the assessment in a pretest, posttest, post posttest design. Data from each year of the grant were analyzed separately. Additional analyses for all three years were conducted and contributed to the overall effectiveness of the project. There was no control group for the study.

Research Questions

The following questions were addressed for the duration of the project. The questions match the goals and objectives

1. Does student content knowledge change as measured by pretest/posttest multiple choice content data?
2. Do student attitudes towards STEM subjects and careers change as measured by the STEM Semantics Survey (Tyler-Wood et al., 2010)?
3. Does teachers' self-efficacy in science education change as measured by the STEBI-A (Enochs & Riggs, 1990)?
4. Does teacher content knowledge change as measured by a multiple-choice content test?

The implementation of the curriculum itself, as well as the intensive and continuing professional development are considered dependent variables that will be manipulated to determine if statistical differences exist, in which the independent variables of STEM interest, content knowledge, and teacher efficacy will be a result of the implementation of the curriculum.

The project outline, goals, and objectives had been laid with the approval of the grant from the National Science Foundation out prior to the researcher collecting data on the project. The researcher's purpose and role in the project was to determine the effectiveness of the project related to the predetermined goals and objectives. The research questions for this study stem directly from the goals and objectives outlined in the grant. The researcher was charged with collecting and analyzing quantitative data to report yearly on the progress of the project towards the grant goals.

Theoretical Framework

Constructivist learning theories lend support to inquiry techniques utilized throughout the program implementation. Creating knowledge through the process of interacting with content and making meaning through those interactions allows students to engage in problem-solving and discourse surrounding the content. Students are active learners, constructing knowledge through the guidance of a teacher, who facilitates thinking and problem-solving (Bruner, 1966). Furthermore, students in the middle and high school grades are cognitively progressing through Piaget's Formal Operations Stage, characterized by a concern for social issues and the ability to solve abstract problems logically (Arends, 2015) making the use of this specific curriculum a valid application within this study.

STEM education provides students with constructivist approaches to learning the content at a deeper cognitive level (Becker & Park, 2011). Although STEM education is a reference to the four disciplines of science, technology, engineering, and mathematics there is no national definition to guide the implementation of STEM (Bybee, 2013; National Research Council, 2013). Most refer to STEM as the integration of at least two of the disciplines, although not necessarily equally (Bybee, 2013). It has also been suggested that STEM education focuses on science with an integration of technology, engineering, or math. Or math content placed within the context of science, engineering, or technology (National Research Council, 2011).

A conceptual framework to understand STEM education positions science education as the initial body of knowledge leading to engineering as a format for solving problems using science knowledge. Mathematical thinking can be understood as the set of tools required to acquire the scientific knowledge implement solutions to engineering problems. Technology's place within the framework serves as the solution to the engineering process as well as the tools to help guide additional scientific inquiries and start the investigative process again (Kelley & Knowles, 2016).

However, due to the lack of clarity in definition, some prefer to use the purpose of STEM education to define what it may look like in a classroom (Bybee, 2013). STEM education should contribute to an individual's knowledge, skills, and attitudes towards issues based in STEM as well as an awareness of STEM and how these issues shape the world around us (Bybee, 2013). Preparing students to use STEM knowledge to inform their decisions and participate in civic affairs remains an important component of STEM education (National Research Council, 2011).

The current project focuses primarily on the integration of science education with engineering and technology. Although math was integrated and used to support these understandings it was not the focus of the curriculum. The values of STEM education hold true with those described by Bybee (2013) and the National Research Council (2011) and focus on obtaining knowledge and applying it through inquiry based approaches. Barriers to STEM implementation include a lack of professional development in STEM education for inservice and preservice teachers (NRC, 2000). The connection between the quality of teaching and student achievement creates a need for strong professional development programs in STEM education (Berlin & White, 2012).

The need for strong professional development to influence student achievement and interests in STEM, thus serving as a lens through which to view the research.

Definitions

- *Inquiry* – a continuum of activities ranging from a didactic approach to teaching (where teachers play a large part in providing the knowledge) to completely open-ended instruction where students are the sole contributors to solving problems, just as scientists, engineers, and mathematicians would in the real world. (Banchi & Bell, 2008; Herron, 1971; National Research Council, 1996).
- *Science* – the intellectual and practical activity encompassing the systematic study of the structure and behavior of the physical and natural world through observation and experiment (Oxford English Dictionary).
- *STEM education* – an integrated approach to teaching science, technology, engineering, and mathematics that engaging students in work that closely mirrors that of scientists and engineers in the real world through inquiry processes (Breiner, Harkness, Johnson, & Koehler, 2012; Bybee, 2013).

Summary

With increased importance placed on STEM education in classrooms it is necessary to ensure students are engaging in multiple levels and types of inquiry activities in STEM settings, ultimately leading to open inquiry in which students are demonstrating the practices of professionals in STEM fields. This will help create students well versed in the multitude of formats in which inquiry is conducted in STEM focused disciplines. Engaging in a curriculum that increases student interest in STEM fields creates a stronger desire to pursue careers and higher education in these fields

(Ozel et al., 2013). To create this type of learning, teachers need intensive and sustained professional development (Desimone, 2009), which develops in-depth knowledge about integrative STEM disciplines, as well as the various levels and methods of inquiry.

Evaluating the effectiveness of an inquiry based STEM curriculum in relation to the three dimensions of the NGSS, is necessary to ensure students are being presented with inquiry lessons that not only increase understanding of phenomena, but also increase student interest in STEM disciplines and careers in order to create lifelong interest in the fields (National Academy of Science, 2013). Inquiry based STEM programs should be integrated at all levels, but research suggests attitudes towards science are established in the middle school years. Interest in quality programs can increase students' desires to enroll in STEM courses, pursue STEM degrees, choose careers in STEM fields (Newell, Tharp, Moreno, Zeintek, & Vogt, 2015).

Evidence from empirical studies suggests students who are engaged in high-quality STEM inquiry programs are more likely to graduate from and to choose careers in STEM fields leading to an increase in the STEM expertise needed to be successful in today's economy and deal with current societal problems (Buckley, 2009; Johnson, 2013). Programs should align to national standards and allow for students to construct knowledge that mirrors the work of professionals in STEM fields and integrate twenty-first century learning skills (Anderson, 2002; Crawford, 2007; Prettyman et al., 2012). Students engaged in open-ended inquiry are more likely to develop the discourse and skill set that mirrors what scientists, engineers, and mathematicians do in their professions, which will prepare them for careers in these fields (Crawford, 2007; Passmore, Stewart & Cartier, 2009). As a result, it is imperative to have programs that address the three-dimensions of the NGSS and appropriately scaffold the level of inquiry within a STEM setting. (NRC, 2013; Scott, 2012). When evaluating STEM programs, consideration as to the type and quality of professional development teachers need to experience success must be made (Johnson, 2013).

Chapter Two: Literature Review

This chapter presents a comprehensive review the literature surrounding the history, current practices and assessment in STEM education. Emphasis placed on best practices, including inquiry, will reveal how to support integrated STEM education across the United States. The historical development of inquiry practices into the three dimensions of the NGSS will be explored, allowing for an understanding of the foundational practices of inquiry in STEM education.

This literature review consists of five major parts. Part one discusses the history of science education from the early 1800s to the present. Thus, establishing the practices of inquiry through constructivism, and revealing literature on the development and inclusion of inquiry as a foundation of STEM education. Part two focuses on inquiry practices and the various methods of utilizing inquiry to develop and understanding of STEM disciplines. The development of STEM education and barriers to implementing integrated STEM is the focus of part three, followed by the history and current literature surrounding research on professional development for science educators. The final section discusses assessment protocols for inquiry and STEM programs and education.

STEM education is encountering a shift from teaching the skills of each discipline independently to teaching all four disciplines together in an integrated approach (Bybee, 2013). By integrating these disciplines together, students gain insight into the natural connectedness of the disciplines and are more prepared for postsecondary studies and careers in a technologically driven society where sciences and engineering are leading the way (NRC, 2013).

Although the need to compete globally is a major factor when creating learning experiences in STEM education for students, it can also be argued that the need for knowledge surrounding various STEM topics is essential for personal reasons. Science, technology, engineering, and mathematics permeate every aspect of society. Understanding the principles that govern the world can lead to personal insights and create new opportunities to explore (NRC, 2012). In that respect, learning STEM education is important for all citizens, even those who do not ultimately choose to pursue these fields as a career.

The Next Generation Science Standards (NGSS) provide a new lens with which to view STEM education, describing a three-dimensional approach to teaching science (NGSS Lead States, 2013). This approach to exists as a refinement of inquiry-based teaching, requiring inquiry practices to support understanding of science and engineering. The creation of the NGSS was fueled with the goals of encouraging interest in science and engineering fields, and providing standards which allow all students to be able to discuss and evaluate scientific related issues (NRC, 2012). The idea of three-dimensional learning provided by the NGSS incorporates Science and Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CC; NRC, 2012; NGSS Lead States, 2013). These three dimensions can be thought of as the foundations of practice (the SEP) for current inquiry based teaching, the content (the DCI), and connections to the real world (the CC). In order to address any performance expectation all three components must be taken into consideration and incorporated into all units of instruction, as well as most individual lessons.

Inquiry as a foundation in STEM education, serves as the approach to teaching students how scientists, technologists, engineers, and mathematicians work and collaborate in the workforce (NRC, 2008). Although differences underlying how each STEM discipline conducts inquiry, the main intent of inquiry remains the same: recognizing the creative problem-solving approaches for each field. Inquiry, defined by practices, includes the ability to identify problems and questions in life, find multiple methods to approach a problem, draw on evidence to base conclusions using models or through interactions with the content, engage in discourse about methods and results, and transfer learned information to new situations (Crawford, 2007; Engineering is Elementary, 2013; Harwood & Miller, 2004; Herron, 1971; National Research Council, 1996; NCTM, 1997). Furthermore, the NGSS define the SEPs as the practices of inquiry and include (1) Asking questions and defining problems, (2) Developing and using models, (3) Planning and carrying out investigations, (4) Analyzing and interpreting data, (5) Using mathematics and computational thinking, (6) Constructing explanations and designing solutions, (7) Engaging in argument from evidence, and (8) Obtaining, evaluating and communicating information (NGSS Lead States, 2013).

The inherent similarities of foundational skills of inquiry in different disciplines allow for the ability to easily integrate these disciplines together into cohesive STEM units and lessons. As a result, new curricula are being developed to not only meet the needs of the NGSS three-dimensional learning, but also to engage students in scientific inquiry, or practices, that mirror those of professionals in the field. These programs also provide evidence of twenty-first learning skills, such as creative thinking, problem solving, and literacy with different tools and information (Prettyman et al., 2012).

Teaching through inquiry using the three dimensions of the NGSS (NGSS Lead States, 2013) allows students to make meaning of different phenomena in various fields through first hand-experiences (Anderson, 2002; Campbell, Oh, & Neilson, 2012). STEM education is highly reliant upon the three-dimensional, inquiry-based teaching to develop habits of thinking and problem solving. Students must be given experiences in which to practice the application of knowledge and skills in order to appropriately apply knowledge and skills in socially relevant, meaningful situations (Bybee, 2013).

History and Development of Science as Inquiry

Science education has undergone major paradigm shifts in the past two hundred years. What was traditionally taught strictly to university students through direct instruction has been made available to the masses in more learner-centered approaches (DeBoer, 1991). This section explores the history of science education and how societal pressures brought about the changes from classical teacher-centered, didactic methods to student-centered, inquiry approaches (DeBoer, 1991).

The development of science education has been fraught with many challenges from its introduction into the classroom, ranging from who should be taught science to how it should be taught. In the early 1800s practitioners realized students understood science better when learning it through hands-on approaches, developing into what is now known as inquiry, rather than a traditional lecture format (DeBoer, 1991). Evolving to meet the needs of learners, inquiry was built on theories and research supporting the construction of knowledge through interactive, discovery approaches (Herron, 1971). Science was not traditionally taught through this inductive method, but inquiry has gained acceptance through continuing research and is now inseparable from the definition of science education.

Progression of the Paper

The current research paper progresses through five chapters including (1) Introduction, (2) Literature Review, (3) Methods, (4) Results, (5) Discussion. The introduction begins with a basic introduction to the literature, a brief scope of Project ReCharge, a theoretical framework from which to view the research, an outline of the research questions, and definitions used to guide the reader into the second chapter which encompasses a complete review of the literature pertinent to the current research. Chapter two reveals the Project's current place from a historical perspective. A history of science, inquiry, and STEM education is developed through seminal works in the areas as well as current research in the areas. Additional literature on professional development in science education, and assessment of STEM and inquiry complete the literature and lead to the method for the project.

Chapter three includes the methodology. A description of Project ReCharge and the grant are included as well as the selection of teacher and student participants based on requirements from the grant. Chapter three also includes assessment selection and creation and statistical analyses utilized for each question addressed in the research. Following the methodology is chapter four, which includes the results for each question for each year of the grant as well as analyses for all three years combined. Chapter five discusses the research findings and implications for future research as well as the limitations for of the study.

History of science education: 1800 to 1900.

The early 19th century saw many shifts in the purpose of education in the United States. Public schools began appearing around 1825, placing importance upon basic literacy and numeracy skills (Arends, 2015). Professional training was not required for teachers whose main purpose was to promote ideas and morals from the local community (Arends, 2015). An overall lack of concern for any pedagogical abilities of teachers marked the period. However, as the roles and purposes of education began to expand additional pressures for teachers to develop habits of teaching emerged. Becoming an institution of opportunity, schools began providing more services to students, and teachers were required to be trained in the subject matter they were teaching as well as develop a sense of how students learn (Arends, 2015).

The creation of teacher schools prompted research focused on cognitive learning theories. One of the first to propose the idea of active learning for students was John Dewey (Bybee, 2002). As he began researching how people think and learn, noting specifically how children naturally think and act through experimental inquiry, which he describes as "near, very near to the attitude of the scientific mind." (Dewey, 1910, p. 11). He concluded students developed cognitive structures by relating different ideas constructed through active learning processes (Bybee, 2002). He criticized school science classes for placing too much emphasis on the accumulation of knowledge, rather than teaching science as a way of thinking about the world (Dewey, 1910).

By the end of the nineteenth century a transition away from classical education (reading, writing, and arithmetic) to a more practical education was made. The frame of mind promoting topics that would ultimately help people in the age in which they lived was established, stepping away from teaching irrelevant topics of the ancient past and placing the learner at the center of education (DeBoer, 1991). Focusing on the learner promoted science education as an important topic for individuals to be successful in their everyday lives. Research at the time also advocated for science to be taught as inquiry, a hands-on approach to learning that "challenges students to form deep understandings about natural phenomena by engaging in the construction of scientific knowledge through an active process of investigation" (Chiappetta, 2008, p. 21). However, developing the pedagogical shifts away from the didactic lecture format popular at the time was yet to be established.

Through the early years of public education up through the late 1800s science remained a topic reserved for higher education. However, in 1893 at the annual National Education Association meeting, a group of college and school leaders were brought together creating the Committee of Ten. The committee was established with the intention of prescribing and standardizing a high school science curriculum as well as promoting better science programs in elementary grades (Chiappetta, 2008; DeBoer 1991). The Committee of Ten was tasked with deciding on the necessary prerequisites for students in high school in order to gain admission into a university as a way of creating more uniform admission requirements at the college and university level (DeBoer, 1991). As well as standardizing admission requirements the committee also recommended that twenty-five percent of the high school curriculum should be devoted to science related topics, a substantial increase from what was required at the time (DeBoer, 1991).

With requirements for science education developed in the secondary setting, and being established at even earlier grades, teachers began to focus on how to teach the facts of science. Many relied heavily on textbook and lecture formats, but some considered the research of Dewey and others and began presenting science to students in real-world, applicable formats. The ideas of Swiss educator Johann Heinrich Pestalozzi were some of the first to introduce the United States to inquiry teaching in the early 1820s through writings of American educators (DeBoer, 1991). Pestalozzi believed "investigation and experimentation were more important than memorization, and activity was more important that passive learning" (DeBoer, 1991, p. 22). His ideas promoted teaching students through their natural interests and activity with a focus on personal understanding. Teachers were forced to interact with the students and the content in an entirely new way than they were accustomed to (DeBoer, 1991).

Stemming from the ideas of Pestalozzi, the late 1800s saw additional learning theories develop. Pedagogy developed by Johann Friedrich Herbart (1824) stressed the interconnectedness of different ideas and concepts developed through a learner-centered approach. The Theory of Interest created by Herbart stated instruction should be interesting to students and peak their curiosity through personal experiences with phenomena and social interactions, thus creating a desire to understand the natural world and pleasure once the phenomena were understood (DeBoer, 1991). These ideas led the way for current learning cycles, promoting an engagement activity as the required first step to any learning situation (Bybee, 2002).

Accounts of early inquiry in science education using learner-centered approaches began to appear in the late 1800s. Alexander Smith, a chemistry teacher in the late 1800s created a laboratory-based class that focused on independent discovery for each student to develop meaningful understanding of the content. This was a change from the traditional lecture hall tasks which populated science courses at the time, and required students to interact with the content to complete the labs. Citing many problems in chemistry education specifically, including poor science education at the elementary grades, poorly trained teachers, and unclear goals for chemistry, he found inquiry instruction provided students with mental discipline as well as information about the phenomena being explored. Smith proposed five contributions that science made to education including observations of the natural world, developing methods of generating knowledge, exercising the imagination, viewing problems objectively, and generating useful information. These contributions provided a rationale to include science through inquiry in schools, even in the elementary grades (DeBoer, 1991).

The introduction of science into the high school curriculum created a profound shift in how education was presented to students at the turn of the twentieth century. Science educators found themselves shifting from a fact based, didactic format to the development of personal understanding of content through learner experiences (DeBoer, 1991). The reorganization of science education had begun. Advocates of inquiry started developing methods of instruction that were closely linked to students' lives. They found pupils were more engaged and would remember and understand topics better using inquiry based methods as compared to the traditional didactic formats for teaching science (DeBoer, 1991). This restructuring led to two trends in the late 1800s. First, students should be taught how to obtain accurate scientific information to prepare them for an industrial society in which they can be active members. The supporting methods for the trend became the basis for inquiry practices, supporting student-centered approaches and understanding being constructed through meaningful, real-world situations. The second trend included teaching students how to prepare for college science courses (Chiappetta, 2008). Although science courses were still largely focused on factual information, practical applications began to appear in more and more classrooms. From this time on, the term *inquiry* began to appear in the literature, referring to the nature of knowledge and how that knowledge is acquired (Bruner, 1966; Chiappetta, 2008).

History of science education: 1900 to 1955.

As inquiry was developing in the early 1900s, learning theories and knowledge acquisition theories began to emerge in education. These theories supported conceptual development through constructivist approaches. Edward L. Thorndike, an American psychologist, spent much of his time researching learning processes through behaviorism and the link between stimuli and response. He held the belief that humans would link new experiences to previous experiences, and that only displayed behaviors could be studied (Collins, 2002). Two parts Thorndike's Law of Effects emerged through his research. First, the more humans practiced a skill the more likely they would be to display that skill, and second if the subject experienced pleasure while completing the task, then the skill required by the task increased. Inversely, if the task led to an unpleasant experience the skill would begin to disappear (Collins, 2002).

Relating behaviorist theories to inquiry focused on the positive emotions students regularly encounter while engaging in activities that were stimulating and exciting. Even though increasing student interest in science through inquiry does not ensure students will pursue those careers, it does trigger student motivation and create a stronger desire to continue exploring these phenomena that exist in society (NRC, 2012). Teaching students how to do inquiry requires teachers to teach and scaffold the skills in a way that encourages students to pursue the problem on their own, thus wanting to do more and more with less and less help. As described by John Dewey (1900) learning takes place in an engaging environment, where students are encouraged to employ problem-solving skills.

As researchers began to understand the cognitive development of how students learn, more theories supporting the use of concrete objects for students to interact with prior to developing abstract concepts was determined as necessary to develop a full understanding of the topic (Piaget & Inhelder, 1969). Requiring students to interact with abstract concepts through experimentation in order to make meaning of the natural world around them, was the basis for Piaget's Theory of Cognitive Development. The theory described the acquisition of knowledge in two parts. First knowledge can be assimilated into previously learned schema, filed away into a folder that has already been created, and second is accommodation where old knowledge is moved around in order to fit the new information (Piaget & Inhelder, 1969).

Piaget's principal mission was epistemological rather than psychological. His research provided evidence of a theory of knowledge and its construction at different points in a child's life (Bruner, 1966). Piaget's Stages of Cognitive Development Theory states learning is affected by a child's age and intellectual development with four stages children progress through in order to approach and solve abstract problems in a logical fashion (Arends, 2015). Individuals must advance through each stage to reach the next. In the Sensorimotor stage, typically from birth to two years of age, children and recognize objects and imitate others. The Preoperational Stage, from two to about seven years is characterized by the use of language, the ability to begin thinking symbolically, and the first steps to seeing another person's point of view. However, children at this age lack logical mental operations. From seven to eleven years, students proceed through the Concrete Operational Stage. Children in this stage are able to classify objects and solve concrete problems in a logical manner. Finally, from eleven years to fifteen years and through adulthood learners develop a concern for social issues and can solve abstract problems in a logical manner (Arends, 2015).

Similar to Piaget's stages of development, Jerome Bruner theorized children progressed through various stages of representation in order to construct knowledge. His three-stage theory began with Enactive representations developed from birth to one year old. At this stage information is learned through actions. This stage is followed by the Iconic representation stage from one to six years old. Children in this stage learn through images and those images are stored in the memory. The final stage is symbolic representation from seven years old to adulthood. At this stage learners utilize symbols and words to expand their understanding of different phenomena. As children grow and mature they rely less on enactive representations and more on symbolic representations (Arrends, 2015). In agreement with the work of Piaget, Bruner described the purpose of education as facilitating thinking and problem solving, not imparting facts upon students (Bruner, 1966). However, in contrast to Piaget, Bruner believed that with appropriate scaffolds children at any age could obtain symbolic representation if they progressed through the representation stages from Enactive to Symbolic (Bruner, 1966).

These theories set the stage for constructivism, the idea that knowledge is created through an active process which, by extension, allows students to make personal connections with meaningful content. This is further enhanced through the interaction and discourse with peers, creating greater intellectual growth (Bruner, 1966; Collins, 2002). It follows then that the use of inquiry to present science topics to students is based within these theories. Joseph Schwab, an educational theorist, was another influential voice supporting teaching science in an inquiry format. He argued teachers should not teach content, but teach inquiry and allow students to discover the content through investigations and evidence (NRC, 2000). Known for creating the Biology Teachers' Handbook, which developed concepts through investigations, Schwab stressed how science was done rather than the basic facts of the science (DeBoer, 1991). His ideas encouraged educators to teach "principles of enquiry" (DeBoer, 1991; 163) that would be revised when needed, just as science was in true professions.

By creating environments which allow students to make meaning of abstract concepts of sciences through actively engaging with concrete models of the phenomena, and giving students the time to discuss the phenomena with each other, teachers are creating a constructivist environment based in Piaget's (1969), Dewey's (1900), and Thorndike's (1905) learning theories. Furthermore, scaffolding these inquiry activities to allow students to master one skill before moving onto a more complex one fits into Piaget's theory, suggesting students need to master each level of concrete thinking before moving into the abstract (Piaget & Inhelder, 1969).

Establishing a research base through supporting theories about how people learn, provided a rationale to include inquiry as a necessary component of science education. In 1924, a report from the American Association for the Advancement of Science (AAAS) was published, stressing the importance of inquiry techniques such as observation, experimentation, and data collection. With the expectation that students would be using these skills in various situations, teachers were encouraged to have students practice using them in various real-world situations (AAAS, 1989). The report stated teachers should start with questions about nature, actively engage students, concentrate on the collection and use of evidence from inquiry investigations, enhance relationship between knowledge and how that knowledge is obtained as well as many others (AAAS, 1989). The result was a focused effort on scientific thinking and less on isolated scientific facts. Unfortunately, a national movement towards inquiry and away from didactic teaching did not completely catch on across the United States at this time (Chiappetta, 2008).

History of science education: 1996 to present.

Today, inquiry is considered a staple of science instruction. Including inquiry techniques to teach science includes surface level knowledge, nature of science practices, deep understandings of phenomena and connections to other content areas, as well as encouraging students to model the actions of scientists (Crippen, & Archambault, 2012). Promoting inquiry as the ways in which scientist conduct their daily work provides a needed rationale for incorporating these techniques into science classes. The skills developed through inquiry are constructed through engaging activities mirroring what professionals in the field would do (Campbell et al., 2012).

The NSES serve as a predecessor to the Next Generation Science Standards (NGSS). The NGSS were created to fulfill two needs, first there has not been a new framework since the NSES in 1996, and second a push for common state standards was developing. The newly created Common Core State Standards in Mathematics and English Language Arts created interest in common standards for science as well. The

NGSS fill that need (NRC, 2012). Encouraging an interest in these fields is one goal of the Next Generation Science Standards (NRC, 2012). A second goal of the NGSS states that by grade twelve people should be able to discuss science-related issues, critically evaluate scientific information, and continue to learn about science in their everyday lives (NRC, 2012). As a direct result of the NSES and Benchmarks for Science Literacy by the American Association for the Advancement of Science, the NGSS are being adopted by many states across the country. Twenty-one states currently have adopted the NGSS, with an additional eighteen using the Framework and three-dimensional learning to guide the development of their own standards.

Although built upon the same research and promoting the same ideas for science education, the NGSS differ from the NSES in several ways, including how much content is being presented to each grade level. There are a limited number of core ideas for each grade which students are continually building upon and revising their knowledge over the years (NRC, 2012). The rationale for limiting the number of core ideas presented to students is built upon the differences between experts and novices in different fields. Experts can look at core ideas and constructs in their fields and apply them across a wide range of scenarios, whereas novices tend to store disconnected facts about the field and struggle to apply them to new situations. Having a limited number of core ideas also allows teachers to cover the content at a greater depth and helps eliminate the shallow coverage of many facts of different areas of science (NRC, 2012). There are intentional limitations built into the standards that allow for teacher discretion. These include the idea that the science and engineering practices mentioned are not exhaustive, nor should they be used as the format for teaching science. Advanced work is not defined in the

NGSS and students interested in scientific or engineering fields should be able to pursue additional work in those areas, and with the wide range of diversity in our country additional supports and interventions should be used where necessary (NGSS Lead States, 2013).

The NGSS are built upon three major dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas (NRC, 2012). The combination of these three dimensions outline the skills needed for all students to be proficient in science by twelfth grade (NRC, 2012). For students to become proficient in science and engineering disciplines, all three dimensions must be integrated into instruction. The three dimensions build upon the idea that both knowledge and practice are important to extend and refine the knowledge and understandings of science and engineering, and connect to the real world (NRC, 2012). Additionally, to meet the demands of each performance expectation outlined in the NGSS all three dimensions must be addressed and assessed.

The first dimension of the NGSS describes the major practices scientists and engineers employ in their daily lives. These practices are reflective of those of inquiry, in order to meet the requirements of these practices they must be practiced in inquiry settings. Due to the multiple ways inquiry has been defined in previous literature, the NGSS seek to specify what inquiry is with regards to the “cognitive, social, and physical practices that it requires” (NRC, 2012; p. 45). Previous documents have too much ambiguity in defining the term inquiry. The NGSS seek to describe inquiry through the eight practices that make up one of the three dimensions in the standards. The term practice refers to the idea that students need to directly engage in the science and engineering practices in various situations and apply the knowledge associated with that discipline rather than learning about them second hand (NGSS Lead States, 2013). The science and engineering practices provide a foundation of what scientific inquiry utilizes. Without defining inquiry practices in standards, students may receive the notion that science is a set of isolated facts only with no practical application. The skills developed in the eight practices will develop students who are critical thinkers and evaluators of scientific information (NGSS Lead States, 2013).

One benefit of inquiry practices is they pique student curiosity and give students an appreciation of the approaches scientists and engineers use daily to solve problems and explain phenomena in the world. Engaging in the practices helps students understand the core ideas of science and engineering as well as how they are connected through the crosscutting concepts (NGSS Lead States, 2013). Additionally, engaging students in the practices is debunking the myth of the standard scientific method and allows students to see the various ways scientists and engineers in multiple fields conduct research. Although there are many different skills associated with inquiry, these eight practices are presented as the set of skills to be understood by everyone. The common myth of a single scientific process that was once promoted by the NSES (NRC, 1996) is no longer accepted, and is fundamentally wrong since scientists and engineers engage in their professions in different ways. Common themes that run through all branches of science and engineering are described the practices. And although the word inquiry is not used, the skills described are precisely what scientists and engineers use in their careers daily (NRC, 2012).

The eight practices outlined in the NGSS are (1) Asking questions in science and defining problems in engineering, (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics and computational thinking, (6) constructing explanations for science and designing solutions in engineering, (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information (NGSS Lead States, 2013; NRC, 2012). Without practicing these skills students cannot fully appreciate scientific nature itself (NGSS Lead States, 2013; NRC, 2012).

The first practice, asking questions and defining problems, focuses on student ability to ask questions in a variety of scientific formats, through observation, research, and about conclusions drawn from scientific investigations. In engineering students define problems using the constraints required in the design. Scientific questions can arise from multiple situations. They can start from curiosity about the world, a model, or other findings. The major difference between scientific questions and other types of questions is the answers to them are supported by evidence gathered through some sort of investigation. Although engineering seeks to solve a problem and begins by defining that problem, engineers may also start by asking questions to help define the problem, criteria, and constraints. Another part of asking questions aside from just beginning an investigation is their use to critically evaluate data and claims or proposed designs (NGSS Lead States, 2013; NRC, 2012). Asking questions is essential to scientists in the field and knowing what a well-defined, well-formulated, testable question is takes practice (NRC, 2012).

The skills associated with asking questions and defining problems builds in complexity from grade band to grade band. Kindergarten through second grade should be able to ask questions based on observations, ask questions which can be answered by investigations, and define a problem that can be solved by improving an object or tool. In third through fifth grade students should be able to do everything in kindergarten through second grade as well as ask questions that involve a changing variable, identify the difference between scientific and non-scientific questions, ask questions and make reasonable predictions based on prior knowledge with patterns and cause and effect, describe engineering problems that can be solved, and define a problem that includes several criteria for success. In sixth through eighth grade students should be able to do everything in kindergarten through fifth grades and ask questions to clarify an argument or an engineering model, determine the relationship between dependent and independent variables, ask questions that can be investigated with available resources and locations, challenge arguments using questioning, and define an engineering problem which includes scientific knowledge that may limit the possible solutions. In ninth through twelfth grades students should be able to do everything in kindergarten through eighth grades as well as ask questions that arise from unexpected results, seek to clarify or determine information and relationships, and evaluate a question to determine how relevant it is (NGSS Lead States, 2013).

The second practice is defining and developing models. This includes creating diagrams, replicas, mathematical representations, analogies, and computer simulations to represent features of the real world. Models can be used to represent a part of a system that is being studied and aids in developing explanations and conclusions. Models can be refined and modified through an iterative cycle to incorporate different variables and can be used to test different solutions to an engineering problem. Models can also serve as a visual aid in representing a prototype or displaying a design feature to others (NGSS Lead States, 2013; NRC, 2012). Models are a tool for thinking for scientists and engineers. They allow for better understanding of phenomena and engineering designs, and help scientists and engineers communicate their ideas (NRC, 2012).

In kindergarten through second grade students should be able to distinguish between a model and the real thing, compare commonalities and differences between models, develop and use models that represent patterns, scale and amounts, and develop a model to represent a tool. In grades three through five students should be able to do everything from kindergarten to second grade and identify limitations of models, work collaboratively to develop models that show relationships between variables, describe a scientific principle or design solution, develop a model to describe a phenomenon, and test cause and effect relationships using a model. In sixth through eighth grades students should be able to do everything in kindergarten through fifth grades plus develop a model with uncertain factors, develop a model to predict phenomena, and use a model to generate data to test ideas. In ninth through twelfth grade students should be able to do everything from previous grades plus evaluation limitations of models and revise those models, determine how reliable a model is, use multiple types of models to describe phenomena, develop a model that allows for manipulation, and support claims based on generated data (NGSS Lead States, 2013).

Practice three is planning and carrying out investigations. In both science and engineering students are expected to plan and carry out investigations. This includes determining the goal of the investigation, designing a course of action to reach the goal, and collecting evidence to support claims. In science, investigations are commonly used to describe different phenomena, whereas in engineering investigations could be used to determine how to fix or improve a system. Over time students' skills in planning investigations becomes more refined and students are expected to determine which variables can be manipulated, which are dependent and independent variables, and how to use data as evidence to support claims (NGSS Lead States, 2013; NRC, 2012). Scientist plan and carry out investigations in order to determine how the world works and create theories based on observation and data they gather. They then need to test those theories over and over to ensure their accuracy (NRC, 2012).

In kindergarten through second grade students are expected to plan and conduct investigations with peers with guidance that produces data used to answer a question. While conducting the investigation students are expected to make observations that can be counted as data to make comparisons, and determine if a tool meets a goal based on observations. In third through fifth grades students are expected to do everything in kindergarten through second grade as well as conduct investigations with peers using multiple variables, evaluate methods for collecting data and determine what changes might occur when the variable changes, and test multiple models and determine which better meets the criteria for the project. In sixth through eighth grades students should be able to do everything in previous grades plus plan and conduct an investigation independently noting controls, independent and dependent variables, produce and collect data to as evidence to support a claim, and evaluate the various methods for collecting data and conducting an investigation. In grades nine through twelve students should be able to do everything in the previous grades as well as manipulate variables to identify failures in a system or make improvements, make a hypothesis based on the results of a dependent variable, conduct investigations ethically, produce and analyze data, and consider confounding variables and how they affect an investigation (NGSS Lead States, 2013).

Practice four is analyzing and interpreting data. As students mature they should be able to use multiple tools to collect data and represent them both visually and statistically. Once raw data is collected, scientists must determine the best way to present the data to others. This may be done through tables, graphs, or statistical analyses. Organizing the data allows for interpretation which can then be used as evidence in an argument. Engineers also analyze and interpret data to improve the model or prototype they are creating. This helps to guide design decisions and determine how well the prototype or model fits the constraints of the project (NGSS Lead States, 2013; NRC, 2012).

In kindergarten through second grade students should be able to record information and share it using pictures and writings, use data to describe patterns and relationships, compare and contrast events using data, and determine if a tool works as intended using data. In third through fifth grades students are expected to do everything in kindergarten through second grades as well as using more quantitative formats for data such using tables and graphs to display data, analyze data make sense of a phenomenon and refine a problem or solution. In sixth through eighth grades students should be able to do everything in previous grades as well as identify linear and nonlinear relationships, temporal and spatial relationships, determine the differences between causal and correlational relationships, use statistics to characterize data, consider limitations of data, and analyze data to determine the range at which an object meets the criteria of a project. In ninth grade through twelfth grade students are expected to do everything from previous grades as well as make valid and reliable claims based on evidence, consider limitations of statistics to represent data, and use data to determine the successes and failures of a system or process (NGSS Lead States, 2013).

Current practices for analyzing and interpreting data include students collecting real-world, real-time data through the use of multiple technologies in order to interpret their meaning and analyze the affects of different variables on those data. Engaging students in collecting meaningful data to analyze is a highly effective tool in developing inquiry-based problem-solving skills (Yepes-Baraya, 2004). This movement shifts control from the teacher to the student and grounds scientific phenomena, promoting data collection that is grounded in the students' environment (Clark, Majumdar, Bhattacharjee, & Hanks, 2015). Incorporating data collecting instruments also encourages student practice and mastery of reading and proper handling of instrumentation, an important component of the NGSS physical science core idea in information technologies and instrumentation (NGSS Lead States, 2013).

In a study conducted by Clark et al. (2015) students utilized weather devices installed at their school site in order to collect and evaluate data in order to gain greater understanding of their local environment. Results of the study indicate students STEM literacy increased as a result of collecting and interpreting data through the use of instrumentation at their school site as well as meaningful discussion about the data they were collecting. Connecting data collection to meaningful real-world issues created a seamless transition between the classroom and professional environments (Clark et al., 2015).

Practice five is using mathematics and computational thinking. In science, math is used as a tool that represents variables and relationships. Some also consider math to be the language of science, since so many sciences would not make sense if math were not included. Students use mathematics for collecting, measuring, and processing data. They are also expected to use computational thinking as a way to organize data, and develop new simulations. Scientists and engineers use mathematics and computational tools to “collect and analyze large data sets, search for distinctive patterns, and identify relationships and significant features” (NRC, 2012, p. 64). Computational tools allow scientists and engineers to process and analyze large data sets and to model complex phenomena (NGSS Lead States, 2013; NRC, 2012).

In kindergarten through second grade students are expected to determine when to use qualitative or quantitative data, describe patterns in the natural world using numbers, and use math to compare different objects. In third through fifth grades students are expected to do everything in kindergarten through second grades plus organize data to display patterns and relationships, use quantities to answer scientific questions and engineering problems, and create graphs and charts to compare different solutions to problems. In sixth through eighth grades students should be able to do everything from previous grades as well as analyze large data sets using digital tools, support claims using mathematical representations, create an algorithm to solve problems, and apply math to scientific investigations or engineering problems. In ninth through twelfth grades students are expected to do everything from previous grades as well as create computational models to represent phenomena and support claims, and apply mathematics at various levels to solve problems and compare outcomes (NGSS Lead States, 2013).

Practice six is constructing explanations and designing solutions. Scientists construct explanations about the natural world. Students should be able to construct their own explanations based on data as well as apply well known explanations to their investigations. Constructing explanations includes interpreting data and relationships between variables. Engineering requires students to design solutions to problems through an iterative process to determine the best way to meet the criteria for the project. Constructing explanations in science serves to create theories that are widely accepted, including the Big Bang theory, and Darwin's theory of evolution. Theories hold up to significant scrutiny, are revised when new evidence arises, and are based in a significant amount of scientific knowledge and evidence. Explanations serve to link observations and data with theories which can then be used in other investigations (NGSS Lead States, 2013; NRC, 2012).

Kindergarten through second grade students should be able to use observations to construct an explanation, use tools to solve a problem, and compare several solutions to a problem. In third through fifth grade students should be able to base an explanation in observable relationships, use evidence to support an explanation, and generate multiple solutions to a problem based on criteria needs. Students in grades six through eight should be able to do everything in previous grades as well as include quantitative and qualitative data in an explanation, use scientific principles to construct an explanation, use the design cycle to complete a design project, and undergo an iterative process to optimize performance of a design. Students in grades nine through twelve are expected to build off of kindergarten through eighth grade skills as well as revise explanations based on data collected, and use scientific reasoning to determine if data support and explanation or conclusion, apply scientific ideas to determine if the data support the explanation, and design a solution to a real-world problem considering criteria and tradeoff considerations (NGSS Lead States, 2013).

Practice seven is engaging in argument from evidence. Argumentation is a process used to reach a consensus about explanations for natural phenomena in science and for the best design solution in engineering. Argumentation is based on evidence collected to derive explanations. Students at all ages are expected to listen to other ideas, compare and contrast ideas, and evaluate the reliability of different ideas and solutions (NGSS Lead States, 2013; NRC, 2012). Scientists engage in argumentation both formally and informally and help to resolve questions of best design, most appropriate techniques, and how to interpret data sets. Argumentation also serves the scientific community as a way to detect bad practices which is important not just to the scientific community but also to the general population in order for them to make informed decisions about science related media (NRC, 2012).

In kindergarten through second grade students are expected to identify which arguments are supported by evidence and which are not, tell the difference between evidence and opinions, listen to others’ explanations, pick out the main points of an argument, construct an argument with evidence supporting a claim, and determine how effective a tool or solution is based on relevant evidence. In third through fifth grades students should be able to do everything from kindergarten to second grade as well as refine arguments based on evidence, critique others’ ideas and explanations, construct an argument with data or a model, determine the effectiveness of a tool by citing evidence about how it fits the criteria of the project. In sixth through eighth grades students should be able to do everything in kindergarten through fifth grade as well as compare two arguments about the same topic by analyzing data, provide and receive critiques about ideas and explanations, construct or refute an explanation using empirical evidence or models, and construct arguments supporting a design solution or device using empirical evidence. In grades nine through twelve students should be able to do everything from previous grades as well as determine the effectiveness of an argument based on new evidence or claims, respectfully challenge others' ideas and explanations, defend claims using student-generated evidence and displaying scientific knowledge, and evaluate different design solutions (NGSS Lead States, 2013).

Practice eight is obtaining, evaluating, and communicating information. The focus of this practice is using print to gain and interpret scientific knowledge as well as communicate information clearly. Materials used for this practice could be scientific and technological reports, Internet sites, and other technical texts (NGSS Lead States, 2013; NRC, 2012). Students need practice in reading scientific texts, even if they are proficient readers. Often in scientific texts, every word is meaningful, so common strategies for reading fictional text do not apply. Scientific texts also include diagrams, symbols, mathematics and other visual tools to represent information. As well as reading scientific texts, students need to practice writing scientific reports. Writing these types of reports requires students to be precise and concise in their thinking, allowing their ideas to be easily communicated (NRC, 2012).

In kindergarten through second grade students are expected to obtain information through grade level texts, determine how images support scientific and engineering ideas, use text features to help make claims, and communicate with others in written form or using models. In grades three through five students are expected to do everything from previous grades as well as summarize and obtain information presented in scientific grade-level readings, support claims using multiple sources of information, and present scientific ideas in multiple written formats. In grades six through eight students should be able to do everything from kindergarten through fifth grades as well as use science textbooks to obtain scientific and technical information, interpret both qualitative and quantitative information presented in multiple formats, and evaluate the credibility of a text. Students in grades nine through twelve should be able to do everything from previous grades as well as paraphrase science textbooks to gain information, use multiple media formats to support claims or solve problems, evaluate multiple texts for validity and reliability, and communicate ideas in multiple formats (NGSS Lead States, 2013).

These eight practices are embedded in the inquiry practices of both scientists and engineers. It is helpful to think of how these inquiry practices are applied in daily work by considering what scientists and engineers do daily. One dominant activity scientists and engineers do daily is investigation and empirical inquiry which includes asking questions, making observations, planning and conducting experiments, making measurements, collecting data, testing solutions, as well as many others (NRC, 2012). These activities are directly related to the practices outlined in the NGSS, which students should be engaging in during scientific and engineering investigations. A second dominant activity scientists and engineers is developing explanations and solutions. This includes mental reasoning and critical thinking which may take the form of imagining plans and solutions, reasoning about cause and effect, making calculations and predictions. Scientists and engineers engage in these mental activities to create theories and models, and may also lead to forming hypotheses and proposing possible solutions (NRC, 2012). A third major activity of scientists and engineers is evaluating evidence and explanations, as well as models, designs, products, and others. All three activities require scientists and engineers to engage in inquiry practices, which are outlined in the NGSS (NRC, 2012). When considering how scientists and engineers conduct their daily work, it is easy to see how the eight practices in the NGSS directly related to the firsthand work these professionals do. Therefore, students engaging in these practices are engaging in inquiry by mimicking the work of professionals in these fields.

The second dimension in the NGSS are the crosscutting concepts. These are concepts that connect the standards to the real world. These are similar to the unifying concepts and processes in the NSES and the common themes in the Benchmarks for Science Literacy (NRC, 2012). The crosscutting concepts bridge the domains, allowing for a more coherent understanding science and engineering. (NGSS Lead States, 2013). These include (1) patterns, (2) cause and effect, (3) scale, proportion, and quantity, (4) systems and system models, (5) energy and matter, (6) structure and function, and (7) stability and change (NGSS Lead States, 2013). These concepts serve as tools so when students encounter an unfamiliar phenomenon, they can rely on their knowledge of these crosscutting concepts to help them make sense of it. Also, using these concepts in a variety of areas will help develop fluency at the wide range of uses the crosscutting concepts have. Just as with the practices, the crosscutting concepts become more complex from kindergarten to twelfth grade (NGSS Lead States, 2013).

The third dimension of the NGSS standards are the disciplinary core ideas. Science knowledge has expanded exponentially in the last hundred years, and it is still growing today. The goal of the NGSS is not to give students all the facts about the different scientific disciplines, but rather to give them the core ideas needed to allow them to acquire more knowledge on their own beyond their twelfth-grade education (NGSS Lead States, 2013). These encompass a limited set of content standards arranged into four domains (1) physical sciences, (2) life sciences, (3) earth and space sciences, and (4) engineering, technology, and applications of science. In order to fit within one of these four categories, the core ideas had to meet at least two of the following criteria: (1) have a broad importance across multiple scientific disciplines, (2) Provide a key to understanding more complex ideas, (3) relate to interests and lives of students, and (4) be teachable and learnable at multiple grade levels (NGSS Lead States, 2013).

The NGSS build upon the idea of science for all. Science is an important human endeavor allowing everyone to participate in issues related to our world and society and make educated decisions based on scientific evidence and argumentation. Even people who choose not to enter into science and engineering fields will benefit from science and engineering knowledge and ultimately lead more enriching lives (NRC, 2012). Furthermore, the standards rely heavily on student interest and the affective filter to make the content meaningful.

History of science education: 1955 to 1996.

The end of World War II played a key role in the reorganization of science education. Jerrold Zacharias, one of the scientists involved in the Manhattan Project and the creation of the atom bomb, was highly involved in the challenge to reinvent American science education. He and others who helped the U.S. win the war, justified these changes claiming that, “our work in the classrooms was absolutely critical to the country’s future” (Atkin & Black, 2003). Another scientific leader in the community included David Hawkins, an assistant to the atom bomb creator, who pushed the need for science education research to improve science involvement in schools, which he felt would also improve science knowledge and applications overall in the United States (Abramson, 2007).

After World War II, the Soviet Union Government and the United States entered into a space race. The competition to reach space first became a high priority for both countries. The U.S.S.R. Government led the way by launching Sputnik on October 4, 1957. This single event prompted the United States to take a stance and promote science education reform. Fear and paranoia were felt across the country, and United States citizens agreed that improving the scientific prowess of the United States would eliminate any Russian threat. Many scientific leaders in the United States seized the moment and fear to encourage the need for advanced science education in the country (Abramson, 2007). Inquiry based education has since served as a major theme in “post-Sputnik science education reforms” (Chiappetta & Adams, 2004).

Another effect of the Sputnik reforms was the changing role of the teacher. Before this time, university level professors were the sole determiners of science content taught in kindergarten through twelfth grade classrooms. After Sputnik, teachers at all levels began developing their own materials and deciding what should be taught, usually through an experimental format followed by providing feedback to others in order to share and refine their knowledge (Atkin & Black, 2003). Through this initial form of professional development teachers became experts in determining the content to be taught to students, and the format in which it would be taught.

The result of the societal changes taking place as a result of the space race was the creation of a plethora of new programs funded by national organizations, such as the National Science Foundation (NSF) to promote scientific literacy. These programs, referred to as ABC programs as a result of their acronyms, included Science – A Process Approach (created by American Association for the Advancement of Science), Elementary Science Study (ESS) and Science Curriculum Improvement Study (SCIS), as well as many others. A common theme was shared among these programs; emphasis was placed highly on process skills, with the idea that the content would be learned through a discovery format during the investigations. Attention to developmental and cognitive abilities established by Piaget, were placed on a higher tier than facts alone. Results of these programs, when compared to traditional teaching methods, indicated that students had higher achievement in science, even with the emphasis placed on process instead of content (Stohr-Hunt, 1996).

Science education was starting to play a major role not only in schools across the United States, but also in society as a whole. In 1990, the American Association for the Advancement of Science (AAAS) published its book titled Science for all Americans which outlined the need for scientific literacy among all Americans (Rutherford &

Ahlgren, 1990). In achieving scientific literacy among all American citizens, the AAAS declared the future of our country will be just, decent, and retain its economic vitality. The need to create a future where all citizens are scientifically literate fell to a project the AAAS created in the mid-1980s. Project 2061 was created to promote lasting reform in science education. The project was created the last time Haley's Comet appeared and the goals of the project were hoped to be met by the next time the comet appeared in 2061, hence the name of the project (Lederman et. al., 2004). The goals of the project include defining the skills and content needed to be scientifically literate in our society, developing curriculum models and maps to be used by districts and states in order to sustain scientific reform, and working with scientific groups and organizations to implement reform efforts (Rutherford & Ahlgren, 1990). These goals are guided by the six ideas outlined in the project including reform must be a long-term commitment and focus on all students, curriculum should reflect lasting knowledge and skills needed by students, and less content in greater depth should be addressed in schools (Lederman et. al., 2004).

The AAAS maintained a strong belief that science education is the heart of reform in our country. The use of an inquiry format for science education was encouraged to create and maintain lasting reform. This included having students practice their skills in real-world formats in order to learn how to think critically, analyze information, communicate ideas and work with others, and make logical arguments based on observation (Rutherford & Ahlgren, 1990). An additional push to have students working collaboratively and problem solving throughout the inquiry processes also held a strong place in the AAAS's description of creating scientifically literate citizens (Rutherford &

Ahlgren, 1990). With inquiry serving as the basis for lasting societal change, national science standards began to emerge.

In 1996 the National Science Education Standards (NSES) were released. These standards are a direct descendent of the Benchmarks outlined in Project 2061. The National Science Teachers Association (NSTA) originally began working on its own science standards, but eventually realized that any standards it put forth would be viewed as company standards, so the NSTA asked the National Research Council to take over the development of the science education standards (Lederman et. al., 2004).

The NSES provided a framework for promoting scientific literacy, building on the work of others before. The goal of the NSES was not to create a curriculum to be used across the country, but instead to define a plan to guide curriculum and instruction (NRC, 1996). Emphasis in the standards was placed on three things students need to know how to do: learn the concepts of science, understand the procedures and reasoning of scientists, and realize the nature of science as a human endeavor (NRC, 2000). For the first time content and curriculum were divided into grade bands, noting qualitative features that should be mastered by the end of each. Grade bands included kindergarten through fourth grade, fifth grade through eighth grade, and ninth grade through twelfth grade (NRC, 1996).

Content standards describe what students at each grade band should know and be able to do, and include the following eight topics: science as inquiry, physical science, life science, earth and space science, science and technology, science in personal and social perspectives, history and nature of science, and unifying concepts and processes (NRC, 1996). However, more than just content standards are defined in the NSES.

Teaching standards were also designed, describing three major areas teachers are responsible for including the structure of science; the skills and knowledge of teaching science, and professional development. The role of the science teacher was placed as a high priority in the NSES, resulting in standards to ensure teachers would be successful at teaching science to students (NRC, 1996).

A prominent feature in the NSES was the focus and importance placed on inquiry. Inquiry was presented in two ways, first as a set of skills students should develop and use to conduct scientific investigations, and second as teaching and learning strategies which enable concepts to be learned through investigation (NRC, 2000). Viewed by the as a natural human curiosity, it is promoted in classrooms as a way to encourage learning based on a child's natural inquisitiveness (NRC, 2000). The standards for inquiry increase in complexity from kindergarten to twelfth grade to match the cognitive abilities of the students, and include both parts of inquiry mentioned above, requiring students to combine the content and the processes of inquiry (NRC, 2000).

Another important component of reforming science education was the use of assessment to guide instruction. The NSES state that assessment should not be viewed as a weekly grade, but a way to ensure that students are learning the science being presented. Program standards and system standards are also in the NSES describing how all components inside and out of school are important to ensure reform in science education (NRC, 1996). Additionally, new curriculum being created to meet the needs of the NSES required empirical data to support how this curriculum was to be implemented (Herron, 1971). Herron stated the need to assess the implementation of these curriculum stems from the need to address how inquiry was being implemented within them and explicitly define inquiry (Herron, 1971).

Inquiry

Developed through constructivist theories, inquiry has should have a prominent place in the science classroom (Bybee, 2002). These hands-on approaches allow students to actively develop their understanding of the world around them and construct knowledge by develop critical thinking, problem solving, analytical and logical reasoning, and see its relevance in our daily lives (Lederman et al., 2004). Inquiry processes are based in active learning, in which students are constantly constructing and refining ideas based on experiences, and embedded in the nature of science (Anderson, 2002). Understanding the inquiry processes used to develop scientific knowledge becomes the focus of science education, thus creating a knowledge about the subjectivity, tentativeness, social and cultural underpinnings, and creative nature of science (Lederman, et al., 2004). Otherwise known as the Nature of Science (NOS) students see science as more than just a body of facts to be memorized, but also a method or process distinct to each discipline and a way of constructing knowledge through empirically based observations and inferences, theories and laws (Lederman et al., 2004).

More than just a hands-on teaching method for presenting science to students, inquiry can be thought of as a way for students to understand content, and the abilities students should have in working with different science disciplines (Anderson, 2002; Bybee, 2002). Additionally, inquiry can be conducted on a continuum ranging from teacher directed to student led. Teacher directed inquiry techniques mimic the traditional scientific method, where students are given a textbook lab to complete step by step. This is in stark contrast to the opposite side of the continuum where students develop their own investigations based on the needs of the questions they have developed (Herron, 1971). A general lack of precision in defining the various stages on the inquiry continuum creates some challenges for those in the field, however the general idea of scaffolding student understanding from teacher directed to student led investigations remains a constant (Anderson, 2002).

Definitions of inquiry and the continuum.

Developed in 1971, the multifaceted inquiry continuum we experience today was established with the idea that inquiry is not one set of practices experienced in a set method, but a spectrum with the standard scientific method on one side and the other side being completely open-ended (Herron, 1971). Thus allowing students to experience "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work… [and] the activities of students in which they develop knowledge and understanding of how scientists study the natural world." (NRC, 2008, page 23). This definition from the National Science Education Standards (NSES) is commonly referred to when describing inquiry and stresses the importance of multiple approaches to inquiry (Anderson, 2002; Crawford, 2007; Crippen, & Archambault, 2012; Keys & Bryan, 2001). These approaches are designed to encourage students to continually ask and consider what counts, what data to keep or eliminate, what patterns are evident, and many other questions. This requires students to think critically about evidence they are gathering in order to develop a scientific claim or explanation (NRC, 2000).

Along with this definition, the NSES include the skills students should be involved in while conducting inquiry, including observing phenomena, asking questions, doing research from books and the internet, planning how to approach the questions, using multiple tools to aid in the inquiry, gathering and interpreting data, posing and explaining solutions to the problem, and communicating the results (NRC, 2008). Reworked in the Next Generation Science Standards these foundational skills are represented as one of three dimensions required within each performance expectation, known as the Science and Engineering Practices (NGSS Lead States 2013). While engaging in inquiry at any spot along the continuum students are continually required to ask questions, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematical and computational thinking, construct explanations or design solutions, engage in argument from evidence, and communicate information (NGSS Lead States, 2013).

Research has shown positive results in student achievement and interests with teaching through inquiry, but the criterion for success and the definition of inquiry change from study to study creating some confusion as to the attributes of a successful inquiry program (Anderson, 2002). Although there are descriptions of what students should be doing and some general principles about how to get students to do them, there is a lack of overall specificity. Inquiry can take many different forms from highly structured, to free-ranging explorations, both of which have a place in the science classroom depending on the goals of the lesson (NRC, 2000).

Defining major inquiry levels along the continuum may help teachers to structure lessons to enable students to move from the teacher directed end of the continuum to the open-ended end of the continuum. The creation of a framework establishing certain processes for the teacher and student at each major point along the continuum would allow teachers to determine at what level of inquiry their students are performing at, and then scaffold subsequent lessons to be less structured or teacher-led. However, creating a framework to represent the vast array of inquiry activities and practices has proven difficult (Herron, 1971). Consideration for creating a framework with which to identify and assess the level of inquiry being executed in classrooms is made more difficult because as inquiry becomes less structured the formats in which inquiry can be done vastly increase. Furthermore, in between each extreme lie an infinite number of inquiries, each with specific qualities that separate it from others (Herron, 1971). Therefore, identifying specific aspects related to the levels of inquiry in a sort of checklist fashion would not cover the range of inquiry practices that emerge as students progress through the continuum from teacher directed to open-ended inquiry (Herron, 1971).

Commonalities do exist between the various levels of inquiry. For example, all inquiry models describe a major component as the ability of the student to verbalize, and explain their understandings about the inquiries there are engaged in. Windschitl (2008) describes the ability to engage in four types of discourse as the background for inquiry. Discussion surrounding what students know and want to know, and how that information is organized place the student at a starting point. Second, conversations surrounding models and how those models support student understanding are held, followed by seeking evidence generated from manipulating variables or making observations. Finally, Students should build claims and construct arguments to support their understanding of the content.

If these discourse strategies alone are to be the determining factor of inquiry, consideration must be paid to what activities students will be creating knowledge from in order to provide these explanations. A plethora of activities could then be defined as inquiry because they use discursive strategies, including research online and in existing databases (Windschitl, 2008). Science education researchers would argue, however, that although research is a necessary part of inquiry, it alone does not constitute inquiry which is based in the constructivist theory of active learning with concrete objects to enhance student understanding of complex reasoning (Collins, 2002).

The NSES describe five essential features in the inquiry classroom, (1) students are continually engaged in scientific questions, whether they be from a text book or created from their own interests, (2) students focus on accurate evidence to create and evaluate explanations, (3) students formulate explanations supported by evidence to answer their questions, (4) students are continually evaluating their explanations and making changes to those explanations when new evidence is gathered, and (5) students communicate their findings and explanations (NRC, 2000). When put together, these practices provide a good foundation for conducting inquiry science. Inquiries can be labeled as full or partial depending on what or how much is given to the students. If part of an exploration is given to the students through a demonstration or textbook it is considered partial. If an inquiry has all five essential features it is considered a full inquiry according to the NSES (NRC, 2000).

Children are naturally inquisitive, and as they begin to experience the natural world around them in their daily lives their personal inquiry process tends to follow certain patterns of engagement, exploration, formulating reasoning, trying to use those reasoning, and changing their reasoning based on their observations (Bybee, 2002). Crippen and Archambault (2012) describe this natural curiosity as children thinking about what is happening, why it is happening, and what will happen next. This type of learning cycle can serve the basis upon which science teachers can create inquiry-learning experiences.

Although defining various levels of inquiry based on what students should be doing is difficult there is some general consensus about the extremes of the continuum. The teacher directed end of the continuum views inquiry as a set of steps to be followed in order to gain certain skills (Banchi & Bell, 2008), so defining aspects of inquiry based only upon this end of the continuum is too specific and does not allow for any deviations away from the standard scientific method (Herron, 1971). On the opposite side of the continuum, open-ended inquiry has so many aspects that can be identified within the inquiry, and not all of them are the same, that it any attempt to define inquiry based on these aspects would be too general to identify the specific level of inquiry students are engaging in (Herron, 1971).

Aside from the variations inherent in inquiry based instruction, variations between the different disciplines of science exist as well. Chemistry students may gather empirical data based upon isolating variables on which to base conclusions, whereas geology students may not be manipulating variables but making observations to collect data in their inquiries (Windschitl, 2008). These variations between disciplines require a framework which is structured to allow for these variations between disciplines (Herron, 1971). Students need a strong understanding of all the various types and levels of inquiry in different scientific disciplines in order to become scientifically literate (Herron, 1971).

The resulting question that is yet to be answered is "how much and in what detail should scientific enquiry be examined for the purposes of science education?" (Herron, 1971, p. 174).

Unfortunately, many times teachers get stuck in presenting only one type of inquiry, and too often it is the teacher-directed inquiry lessons. On the more conservative side of the continuum, these "cookbook investigations" present only one type of inquiry and set of practices commonly known as the scientific method. Furthermore, these lessons are so scripted and linear, students who engage in them all the time realize they don't need to use any reasoning skills, they just follow the directions given to them because all the tough decisions have been made for them, thus eliminating the benefits of inquiry (Clough, 2002; Windschitl, 2008). Typically, these types of lessons represent only one, very limited format for inquiry. One that closely represents the standard scientific method of ask a question, make a hypothesis, create a procedure, test the hypothesis, gather and interpret data, and state conclusions (Bybee, 2002). This method is over simplified and does not represent the many types of inquiries, or the differences that exist between different disciplines. Neither does it allow students to view a scientific phenomenon from multiple perspectives (Clough, 2002; Harwood & Miller, 2004). Additionally, this reinforces the misconception of only one scientific method (NRC, 1996 & 2000).

Problems arise with the scientific method including the misconception of only one type of inquiry, direct experimentation, in which students can collect data (Windschitl, Thompson & Braaten, 2008). This misconception is prevalent in society, within textbooks, and among many science teachers (Bybee, 2002). Direct experimentation presents students with a systematic, step-by-step format to investigate variables and recognize differences between them, but does not take into consideration the disciplines that do not use direct investigations in order to collect data (Bybee, 2002; Herron, 1971; Windschitl et al., 2008). The scientific method results in a very narrow view of inquiry. Furthermore, not all science disciplines approach inquiry in the same format. Natrualistic inquiry depends more on observation and description, and cannot be adequately done in the highly controlled environment created by the misconception of a single scientific method. Therefore, inquiry is better defined by a continuum of practices rather than a procedure.

The scientific method can also affect students' reasoning skills. Since the method does not require students to have any understanding about the phenomenon, students are only able to characterize the outcomes based on the conditions in the experiment, thus lacking the cognitive skills required for deep understanding of the content (Clough, 2002). They cannot extend these conditions to other areas and create new inquiries from the results of the first experiment (Windschitl et al., 2008). Students need to know not only what happened, but also why, and the relationship between the results and real-world scenarios (Windschitl et al., 2008). Another problem lies in teacher pedagogy. The scientific method works too well for schools. Since the scientific method is a linear model which presents steps that are completed only after the previous one is finished, without the requirement to revisit that step again, it comes to a neat close in a class period or two after which a new inquiry using the same scientific method will start (Windschitl et al., 2008).

The traditional scientific method does not encourage scientific habits of mind, however it can serve as a starting point for inquiry investigations, and a springboard for teachers to start shifting teaching to more open ended inquiries. When used in a step-by-step, linear fashion the scientific method alone does not build the skills required to progress to open-ended, student-led inquiry. However, when the scientific method is not presented in a linear fashion it could move students along the inquiry continuum to more student-led investigations. Harwood (2004) argues the elements of inquiry are present in the scientific method, but they need not be approached in a linear format. This provides a familiar scaffold for both teachers and students but starts to eliminate the step-by-step model used as a starting point in teacher-directed inquiry.

Harwood's activity model uses the steps and skills presented in the traditional scientific method, including communicating with others, observing, defining the problem, forming the question, investigating the known, articulating the expectation, carrying out the study, examining the results, and reflecting on the findings (Harwood & Miller, 2004; Herron, 1971). However, there is no starting or ending point. The steps and skills are repeated and returned to as often as needed until the needs of their investigation are completed. This requires students to think about the results they are getting during the investigation and reason about them, then make decisions as to what they need to do next (Harwood & Miller, 2004). This results in the teacher relinquishing control to the students and forcing them to use inquiry practices to make sense of the data they are collecting through their investigation (Harwood & Miller, 2004).

In order to guide students from the teacher-directed end of the continuum to the open-ended side, it is crucial for teachers to understand the differences between the various levels of inquiry and how to progress students from one level to the next. To make certain points on the continuum more explicit, some researchers have identified specific qualities that can easily be expressed to students and aid in designing a series of scaffolded inquiry lessons, leading students from teacher directed to more open-ended inquiries that model scientists in real-world situations. These inquiry levels serve as a model for teachers to ensure they are engaging students in more rigorous inquiry activities as the year progresses. An increase in comfort with learning cycles can lead to teachable moments, where engaging activities are presented to students but the ideas surrounding the phenomenon are just out of reach, creating a desire in the students to learn what is happening (Bybee, 2015).

Charles Schwab (1968) created one of the first inquiry models delineating three levels from teacher directed to open-ended. The first being a textbook and following an investigation prescribed therein. The second level would use a textbook to pose a question, but the methods would be left out, allowing students to figure out how to approach the problem and find an answer. His final level consisted of students creating their own investigations from their own experiences and desires, not from a textbook, allowing students free-range to build their investigation how they see fit (NRC, 2000). This last level would be the most open-ended format for inquiry.

Heather Banchi and Randy Bell (2008) defined the format for one of the most commonly used levels of inquiry today, describing four levels of inquiry in which teachers should engage students in to lead them into open-ended inquiry. The first level and most teacher directed is confirmation inquiry which is described as students being given the question, procedure, and solution to an inquiry in order to confirm a principle and focus solely on the process involved within that inquiry. Confirmation inquiry is useful to confirm previously learned content and theories, or to practice certain skills (Banchi & Bell, 2008). Completing several confirmation inquiry activities with different focuses and methods would allow students to identify the different paths taken to get a solution, and recognize the differences between disciplines. The second level of inquiry described by the authors (2008) is structured inquiry where students are given both the question and procedure but must come to their own solution and use evidence to support it. Structured inquiry can be useful for students to be able generate explanations based on evidence collected in the provided method. The third level of inquiry is guided inquiry where students are provided with only the question and must identify a method to use to approach the problem and then come up with a solution based on data from their inquiry. Guided inquiry provides students with appropriate questions that are meaningful and allows them to identify an appropriate method to address the question and generate explanations. The final level of inquiry is open inquiry where students are investigating questions they came up with, and creating an appropriate method and finding a solution to their initial problem (Banchi & Bell, 2008).

As students progress through each level of inquiry from confirmation to open they are learning how to conduct inquiry investigations one step at a time, not just being thrown in the deep end and being told to do inquiry with no supports. This gradual release allows students to become proficient with the skills required at each level before moving onto the next. A benefit of defining major levels of inquiry on the continuum is it helps teachers prepare and implement inquiry lessons with their students (Banchi and Bell, 2008). Having defined characteristics for each level allows observers, as well as teachers, to identify the level of inquiry in which students are engaged in, what types of inquiry they have already completed, and which level of inquiry students will be engaged in next (Banchi & Bell, 2008).

Learning cycles.

Once the basic progression of inquiry is established, consideration must given as to how to implement and prepare lessons that meet the level of inquiry for the phenomenon being explored. Within a science inquiry model a learning cycle can be used in order to help students approach and learn the content. Learning cycles stem from Dewey's Model of Experiential Learning created in 1904, and include an impulse for the student, observations, knowledge learned about the impulse, and judgment (Cited in Wenning, 2011). Through continued interaction within this cycle, students gain knowledge about the world around them. Piaget's developmental theory served as a basis for many learning cycles, and influenced Karplus to create the learning cycle commonly used today, although with some modifications. Karplus' instructional model included an exploration, invention and discovery (Karplus & Their, 1967; NRC, 2000). The exploration includes students gathering new information, the invention refers to the new concept being introduced and assimilated, and the discovery refers to the students applying the new concept to new situations (NRC, 2000). Today, several learning cycles exist that create similar learning experiences engaging students in activities that require them to think about phenomena and make new knowledge based on the activities presented to them (Bybee, 2002; Wenning, 2011; Gowen & Alvarez, 2005).

Another example of a learning cycle is implemented in Wenning's Levels of Inquiry Model of Science Teaching (2011). Within each level of inquiry the author describes a learning cycle, which creates more sophisticated process skills as students' progress through the learning cycle as well as through the levels of inquiry. Each of the following should be included within each inquiry students do; first is an observation of the phenomenon, second is a manipulation of models, third students make generalizations based on their observations and manipulations. In the fourth stage, verification, students validate or change their generalizations based on data, and lastly is the application of the data which includes sharing results, discussion of the tasks completed throughout the inquiry, and how those results support the conclusions reached (Wenning 2011).

One of the most commonly used learning cycle designed for teachers to prepare science inquiry activities is the BSCS 5E Instructional Model (Bybee, 2002). In this model students are led through a series of investigations and extensions that builds upon their knowledge with each step. There are five steps in creating a 5E Lesson: engagement, exploration, explanation, elaboration, and evaluation. Each has a distinct purpose and when implemented correctly can lead to teachable moments in students (Bybee, 2015).

The BSCS 5E learning cycle starts with an Engagement activity. This may be a teacher demonstration, read-aloud, structured activity, or discrepant event and allows teachers to identify misconceptions and prior knowledge students may have. The purpose of this activity to activate student background knowledge and get the students' interest. The experience must be relevant and meaningful and may result in students with puzzled looks (Bybee, 2015).

The second step is Explore. In this phase students test their hypotheses against others in order to make new meaning from the data they and their peers are collecting.

The Explanation phase follows with academic language and formal education being implemented at this time. The fourth phase is Elaborate, which allows students to incorporate their newly learned language from the explanation phase and fit it into new situations. The final phase in this model is the Evaluate phase. This phase is a summative assessment for the teacher to assess what students have learned throughout the experience (Bybee, 2002). A model like this allows students to work with laboratory investigations, technology, discuss topics, and work collaboratively all while engaging in inquiry practices. This cycle can be adapted to any level of inquiry.

Yet another learning cycle is Gowin and Alvarez's Vee Diagram (2005). This diagram represents a giant letter "V" with knowledge on the left side of the v and the actions needed to address the issue on the right side. Right in the middle of the v is the big question or problem students are being faced with. Students start on the right and identify initial information or ideas about the problem, they then engage in activities to gain knowledge about the problem, lastly they reflect on their ideas and present claims based on evidence (Crippen, & Archambault, 2012).

Another example of inquiry models upon which teaching practices can be built, and inquiry skills can be scaffolded, is the Levels of Inquiry Model of Science Teaching (Wenning, 2011). In this model, six levels of inquiry are defined. A major focus of this type of inquiry model is based on student discussion and explanation throughout all the levels. From the first level of inquiry to the last students are being required to engage in deeper understanding and more rigorous discourse strategies and tasks.

The first level is discovery learning. In this type of inquiry students are being shown and are interacting with a phenomenon. After they see the phenomenon they are asked to answer “what” and “how” questions based on their initial observations. The purpose of this type of inquiry is for students to develop concepts based on their observations. The second level of inquiry is interactive development. Here students are presented with a demonstration and asked to think about what will happen and why. Throughout these demonstrations students are actively engaging in discourse with their peers and are writing and discussing the phenomenon with peers. The pedagogical purpose of this level is to engage students in discourse that allows the teacher to identify misconceptions and identify prior knowledge. The third level of inquiry is an inquiry lesson where students are being talked through and are engaging in the process of choosing questions, defining variables, and identifying multiple methods to address the problem. Throughout this process the teacher is using the “think-aloud” process guiding students through the inquiry process. Students then engage in the inquiries discussed as a group while the teacher looks on and intervenes when needed. Through the inquiries, students begin to develop theories based on the data they have collected. The fifth level of inquiry is called real world applications. In this level, students are actively defining their own questions and carrying out their investigations. At this stage the students have taken all responsibility for the inquiry (Wenning, 2011).

An instructional model developed by Lederman et. al., (2004) includes five stages that scaffold learning from teacher modeling to student independent practice. The first segment includes an introduction where student background knowledge is being addressed. A teacher demonstration follows so students can see the processes being used. Next is a guided practice where students are actively practicing what was demonstrated while the teacher observes and steps in when needed. The next step is independent practice where students apply their newly acquired skills to a new scenario. The final step is closure where students includes a debrief of the learning objectives and activities.

Instead of focusing on individual levels with certain attributes and roles for the teacher and student, some researchers advocate a method of approaching and scaffolding inquiry that is based on students creating models (Campbell et al., 2012; Windschitl et al., 2008). These models serve as the basis for what students know and are able to articulate about a phenomenon (Windschitl et al., 2008). Model-Based Inquiry (MBI) is described as "an instructional strategy whereby learners are engaged in inquiry in an effort to explore phenomena, and construct iterations models in light of the results of scientific investigations" (Campbell et al., 2012, page 294). These models could be concrete examples of the working phenomena, or discursive models in which students explain the phenomena using data collected through inquiry investigations (Campbell et al., 2012; Windschitl et al., 2008). These models "represent ideas – ideas of how the natural world is structured or how it operates." (page 4), and also represent bigger ideas such as laws and theories (Windschitl et al., 2008).

As students engage in inquiry practices they are continually revising models they have previously created to accommodate new or inaccurate information. Throughout this process students are engaging in discourse with others including debating, narrating, retrieving information, reformulating, elaborating, negotiating, and building on shared information (Campbell et al., 2012). Discourse during investigations allows students to begin to understand how scientists work together to formulate ideas cooperatively, and develop skills for sharing and explaining phenomena (Windschitl et al., 2008). In order to create these highly discursive settings teachers need to plan engaging inquiry activities

(Windschitl et al., 2008). These activities should be motivating, enticing, and encourage multiple formats for approaching a problem. If the inquiry activities lack the features, which allow students to become engaged in the topic, the resulting discourse will not go beyond surface level explanations or increase student understanding of the world around them (Windschitl et al., 2008).

Throughout these types of MBI activities students are constantly making sense of the world around them through academic discourse. After collecting data, it must be used as evidence to support an argument (Windschitl et al., 2008). Students cannot simple state what they did in their inquiry investigation, but must reason through how the data they have collected supports different explanations (Windschitl et al., 2008). Argumentation and discourse strategies in inquiry activities are an important component of learning how to act like scientists. Students are continually asking questions, gathering and discussing evidence, reasoning critically about the data, and then using the information gained to evaluate and support claims (Crippen & Archambault, 2012). However, not all phenomena can be modeled, creating a limitation of only using MBI as a method of instruction. The difference between these types of inquiry teaching methods is how inquiry is scaffolded. Banchi and Bell (2008), and Wenning (2011) describe specific levels of inquiry on the spectrum with specific attributes for each one, whereas the use of MBI focuses more on the discourse associated within inquiry, and not on specific levels students engage in.

There are many similarities between the different STEM disciplines related to how each field engages in inquiry. However, there are some major differences as well. One major difference between science and engineering inquiry lies in the desired outcome based on the definitions of each discipline. Science is defined as a body of knowledge about the physical and natural world, and based on observation and experimentation. In the kindergarten through twelfth grade context, it includes the traditional sciences of physics, chemistry, biology, and earth, space and environmental sciences (NGSS Lead States, 2013), in contrast, engineering is the application of those science facts to design apparatus and processes to fill a need (Engineers' Council for Processional Development, 1947). A school setting, engineering refers to engaging in the systematic process to achieve solutions to human problems (NGSS Lead States, 2013). In other words, the desired outcome for science inquiry is to understand the scientific principles governing the phenomena, whereas the outcome for engineering is a product or process that fills a need (NGSS Lead States, 2013).

The inquiry continuum still applies to engineering inquiry, in terms of teacher-directed on one side, and open-ended on the other side. However, the types of inquiry and formats to present it to students are different. Similarities between science practices and engineering practices include gathering data, identifying constraints, and generating solutions (Kruger & Cross, 2006). Science uses learning cycles such as Bybee's 5E learning cycle (Bybee, 2002) in order to teach students the necessary steps and skills to complete an inquiry investigation. Engineering has a similar learning cycle called the Engineering Design Process (National Center for Technological Literacy [NCTL], 2004). This process represents the cycle engineers go through when creating new products. Instead of starting with a question that needs to be answered, engineering usually starts by identifying a problem and ends with a product or process to fulfill the need of that problem (NGSS Lead States, 2013).

One version of an engineering design process was created by the National Center for Technological Literacy for the Museum of Science, Boston (2004). In the elementary version of this process students start with a problem and discuss the restraints of the problem (time, money, resources). Following the discussion students go through the imagine phase. In this phase, students must imagine different ways the problem could be solved using their previous knowledge. Previous knowledge may be scientific principles they have learned from previously completed scientific inquiries. Following a brainstorming session, students plan their approach to implement their designs. The next step involves creating a prototype of their design and determining how well it fits the criteria and solves the problem. Then the entire cycle is repeated in order to improve and refine the prototype using the information they learned from previous iterations of the process (NCTL, 2004) Certain variations of the engineering design process include a research step right before the imagine step, and a communicate step after the creation and testing of the prototype for students to share and discuss their work.

Research by Kruger and Cross (2006) identified four types of models students tend to follow when faced with engineering tasks. To identify these methods, Kruger and Cross observed nine engineers working on small design projects. The task presented to these engineers was to create a trash system for a new train. Participants were directed to use a think-aloud method so observers could identify trends in their thinking patterns. They each received two and one-half hours to work on the task. During this time, two video cameras were recording the participant.

The first is problem driven design. Students following this type of model tend to focus closely on the features of the problem, and finding a solution as quickly as possible.

As a result, students only use information pertinent to the problem, and do not extend their searches to related areas. A second method is solution driven design. Here students focus on creating multiple solutions, and don't pay specific attention to the details of the problem being presented. Any additional information sought out by the student tends to be related to finding additional solutions to the problem. A third method is information driven design. In this method, students focus on finding all information related to the problem, or possible solutions to the problem and incorporating that information to find a solution. A final method students tend to use when solving engineering problems is knowledge driven design. Students focus on prior knowledge rather than searching for external information (Kruger & Cross, 2006).

It is important for all teachers to plan inquiry using multiple approaches to teach students in an active way, noting details in the different ways science can be done in various STEM fields (Anderson, 2002). Since inquiry involves the students and the teacher, there are very specific roles each plays in this type of reformed teaching. Previously, teachers were seen as dispensers of knowledge, transmitting information through lecture and textbooks (Anderson, 2002). In inquiry settings, the teacher serves as more of a facilitator, creating environments to encourage students to think about the problems and discuss how to approach it with peers. The teacher guides students in the right direction, but also allows students to make mistakes and learn from them (Anderson, 2002). Active learning promotes sense making and helps students organize ideas they are learning into meaningful concepts (Anderson, 2002).

The transition from learning about content to figuring out phenomena in the NGSS appear in the integration of the SEP into each performance expectation. The eight practices described in the NGSS serve to focus the inquiry practices into each performance expectation via three-dimensional learning. The term ‘practice’ is used instead of ‘skill’ to refer to the acts of engaging in science and engineering in relation to the content, not just a employing a procedure alone (NGSS Lead States, 2013). These practices expand beyond just knowing scientific concepts to understanding and investigating using the foundational practices of science and engineering.

STEM Education

Integrating content into one lesson, known as STEM education for science, technology, engineering, and mathematics, is typically built around real-world problems. The idea of integration stems from the idea that real world problems are not concerned with just one discipline, so these topics should not be taught in isolation in schools (Lederman et al., 2004). Furthermore, it’s argued that students will need experiences that blur the boundaries of these traditional disciplines to be successful in their futures (Bybee, 2013).

Definitions of STEM.

The definitions of STEM education are as varied as those for inquiry. There is currently no national definition for STEM education. In some reports STEM emphasizes only one discipline or is seen as standard coursework to be completed, whereas in others all four disciplines must be integrated to be considered STEM (Breiner, Harkness, Johnson & Koehler, 2012; Bybee, 2013). The United States Department of Education describes STEM education as “Science, Technology, Engineering, and Mathematics education programs are defined as those primarily intended to provide support for, or to strengthen, science, technology, engineering, or mathematics (STEM) education at the elementary and secondary through postgraduate levels, including adult education" (U.S. Department of Education, 2007). In most research the combination of at least two STEM disciplines qualifies a lesson as STEM (Berkeihiser & Ray, 2013; Brown & Borrego, 2013; Bybee, 2010; Bybee, 2013). Additionally, STEM does not have to address each subject equally, but rather focus on one subject with the integration of the others to support understanding and allow for transfer (Bybee, 2013). This integrated approach is not a separate subject, but rather builds on the natural connections between the different STEM disciplines.

The commonality across all definitions is the need for collaboration between science, technology, engineering, and mathematics subjects. The emphasis is on the integration and natural connections of the content, not necessarily on how that content is being presented to students, although there is a general agreement that STEM education is a switch from traditional didactic approaches to more project based learning experiences (Breiner et al., 2012). This interdisciplinary approach takes into consideration real world applications of STEM disciplines, and connects the school, community, and global enterprise (Tsupros, Kohler & Hallinen, 2009).

As a result of the multiple definitions of STEM lessons, many prefer to use the definition of STEM literacy as the goal for STEM education (Bybee, 2013). As defined by Bybee (2010; 2013), STEM literacy refers to four different aspects. This includes the individual's attitudes toward and ability to identify important questions and problems in life, to understand STEM as human knowledge, to be aware of the connections in STEM that shape our world, and the individual's willingness to participate in STEM related issues within our society (Bybee, 2010; 2013). STEM literacy also refers to an individual's ability to learn science, technology, engineering, and math knowledge and apply that knowledge to issues within our society (Bybee, 2010).

To create unified STEM classrooms across the United States, a common definition for STEM must be created in order to clarify what it means for teachers, programs, and practices (Bybee, 2010). For example, STEM education should be a recognition of the diminished science education as a result of No Child Left Behind. There should be increased emphasis on engineering in kindergarten through twelfth grade classrooms, and technology use in all classrooms, there should be a heavy focus on 21st century skills, and STEM should be taught in an integrated approach which blurs the boundaries between disciplines and eliminates the silos which content is so often taught (Ashgar et al., 2012; Bybee, 2010). The NGSS strive to elevate STEM education by raising engineering design to the same level as scientific inquiry in classroom instruction when teaching science disciplines at all levels and by giving core ideas of engineering and technology the same status as those in other major science disciplines (NGSS Lead States, 2013).

STEM history.

Integrating several topics together in large thematic units dates back to the 1920s (DeBoer, 1991). Subcommittees were created in each science field to determine what content should be taught in which classes, as a result it was generally agreed upon that the principles, laws, and theories should not be taught in isolation as independent facts, but organized into larger units in which relationships could be recognized. (DeBoer, 1991). The purpose of STEM today is not clear, four disciplines are referenced, but how to teach those four disciplines is not clearly defined (Bybee, 2013). Rationales for integrating these four disciplines include the natural and logical connections found between the content, similar skills needed to solve problems in each discipline, overlapping content, and making content relevant (Berlin & White, 2012). Creating STEM environments also fosters understandings of STEM issues real world problem solving which usually tend to be interdisciplinary by nature (Ashgar et al., 2012).

Creating STEM classrooms have been promoted as a way to promote 21st century skills needed to ensure a global competitiveness for the United States, and many initiatives have passed through congress to fund the implementation of these programs in schools (Atkinson, 2012; Breiner et al., 2012). The significance of creating 21st century learning skills in students is immeasurable, as the demands of globalization requires students to be proficient in the skills in which they will work and perform (Crippen & Archambault, 2012).

In 2010 the America COMPETES Reauthorization Act created a National Science and Technology Council (NSTC) to research current STEM programs and determine where federal monies should be spent. The NSTC identified six goals to report on annually including the following three, to "support the development of a Federal five-year strategic STEM education plan;…[to] support sharing of effective STEM education program strategies and evaluation techniques across the Federal agencies;… and [to] increase awareness of STEM education programs within and across Federal agencies." (National Science and Technology Council, 2011, p. 1). In order to do so the Federal Investment in STEM Education (FI-STEM) created several tools. First a common, consistent definition was determined as well as an extensive survey with questions with a range of many different characteristics to serve as an inventory (NSTC, 2011).

It was determined that of the total education budget, only 0.3% was spent on STEM education. Agencies could invest money in the following areas; learning STEM skills, engagement in STEM, preservice and inservice educator education, postsecondary STEM degrees, STEM careers, institutional capacity, STEM system reform, and education research and development (NSTC, 2011). The majority of money was invested in postsecondary STEM degrees, with preservice and inservice educator education being one of the least invested areas (NSTC, 2011). In order for teachers to effectively teach STEM education, money must be spent to provide them with effective instruction techniques.

Current literature in STEM education suggests there is a research base for studying current practices across the country (Brown, 2012). Research being conducted in STEM education focuses around seven different methods, according to Brown (2012) including, STEM activities, descriptions of STEM programs, editorial pieces on STEM, literature reviews, mixed methods studies, qualitative studies, and quantitative studies. These different methods held different outcomes for STEM education. The outcomes include standards development, engineering education, integrative STEM approaches, science education, implementation, and technology education (Brown, 2012). This suggests there is research on STEM with a variety of methods and outcomes, but more needs to be done in the form of rigorous quantitative and qualitative research with large data sets in order to determine the effectiveness of various programs (Brown, 2012).

Barriers to STEM.

Barriers to teaching STEM have arisen as a result of the lack of a clear understanding of what STEM should be. Studies have found teachers in the same school have different definitions of STEM education, and therefore present STEM education in very different ways (Briener et al., 2012). In many STEM labeled classrooms, these four disciplines are still taught in silos, with a lack of understanding of how closely these topics are related (Breiner et al., 2012). Many times teachers are not familiar with inquiry formats to teach these topics as they would be approached and used in the real world (NRC, 2000), forcing teachers to struggle to teach integrated STEM, or teach how they always have; through direct instruction. Additional misconceptions commonly held by practicing teachers include inquiry being only open-ended, and not allowing for teacher directed instruction, and a misinformed view that hands-on learning and inquiry are the same thing (Lantz, 2009).

This represents a gap in communication between different parties trying to promote STEM including policy makers, k-12 teachers, university representatives, and parents (Breiner et al., 2012). In a qualitative study conducted by Breiner et al. (2012) researchers identified several themes when asking these groups “What is STEM” and “How does STEM influence and/or impact your life?” (Page 6). In response to the question “What is STEM” 161 out of 222 participants stated a relationship between science, technology, engineering, and math. Of those, 57% stated just the acronym, 9% described the acronym. The second question was answered by the same population and three themes emerged including a null relationship with STEM, a personal relationship with STEM, and societal issues relating to STEM. Further results indicated 36% of this group responded with a null relationship to STEM stating they did not know how STEM impacted their lives.

As well as defining STEM, studies need to be conducted to determine how different teaching styles and methods impact student learning in STEM classrooms, rather than just focusing on current trends and a top-down style of implementing STEM education (Williams, 2011). Still others believe that encouraging and funding the ‘STEM for all students’ movement will not be beneficial to our country’s economic growth (Atkinson, 2012). Atkinson (2012) believes encouraging this movement is detrimental and instead promotes increasing STEM learning just for those who are driven to succeed in these fields. He further states everyone learning STEM fields is like asking everyone to learn to play the piano and have access to prestigious music teachers, and top of the line instruments (Atkinson, 2012). In other words, STEM education is not for everyone, and we should not waste resources on those who will not succeed or do not have an interest in those fields.

Another barrier that is becoming more prominent across U.S. kindergarten through twelfth grade schools is the lack of sufficient training in how to teach STEM. Deficiencies in adequate content knowledge or background knowledge to teach in these areas is also occurring (NRC, 2000). One reason preservice teachers are not entering classrooms prepared to teach in a STEM environment is faculty from universities and colleges may not be aware of the current expectations in kindergarten through twelfth grade STEM classrooms, or have the appropriate professional pedagogical development to prepare preservice teachers for these environments (NRC, 2000).

Furthermore, once teachers enter the workforce there is very little professional development to support their efforts in the classroom, and most states do not require teachers to earn content specific degrees, again leading to insufficient knowledge (NRC, 2000). In order to maintain a level of comfort when teaching STEM many teachers must go seek out professional development on their own and at their own expense (NRC, 2000). Additionally, middle and high schools are still commonly departmentalized. Teachers of different fields may plan together but seldom teach integrated lessons, developing a level of personalization with STEM in mind, however not institutional changes (Lantz, 2009). These barriers show a lack of commitment to STEM education at a national level, and must be addressed in order to increase the priority of STEM training for preservice and inservice teachers (Lantz, 2009).

Inquiry Within STEM Education.

Creating inquiry opportunities within STEM settings creates 21st century skills, including adaptability to persevere when unknown conditions arise, communication and social skills, non-routine problem-solving skills, self-management to work in a variety of situations, and understanding systems (Bybee, 2013). Twenty-first century learners know how to think, not just what to think (Prettyman et al., 2012). These skills, as well as the inherent skills associated with inquiry, have become a signature of STEM education, and are considered necessary in order to appropriately implement STEM units (Crippen, & Archambault, 2012).

Despite the barriers that arise when creating STEM classrooms across the United States, many teachers have found ways to successfully create inquiry learning environments that encompass at least two STEM fields. These environments encourage student excitement about STEM activities through a hands-on approach (Ejiwale, 2012). In a study by Berkeihiser and Ray (2013) calculus high school students in Pennsylvania engaged in a lesson, which required them to build cross-sections of three-dimensional solids from layers of hand-cut foam pieces. These represented models commonly used by engineers when designing prototypes. Creating these models by hand forced students to think about the appropriate tools necessary for the task, as well as how to create the accurate three-dimensional model. After the hand-created models were completed, the calculus class teamed up with engineering students in order to create computer models of different cross sections, and then use print out the computer models to use as prototypes. The students in each class learned how to work together and acknowledge the different skills each brought to the project. The engineering students were able to see how calculus played an important role in the computer work they had been doing, while the calculus students were able to see the application of the math they had been learning. The students were able to problem solve to create the needed models and computer programs for the task, and work cooperatively to create the finished product.

To ensure students receive these types of inquiry lessons within STEM settings, it is important to adequately prepare teachers and preservice teachers for the task. In a qualitative study conducted by Berlin and White (2012) preservice teachers' attitudes and perceptions towards STEM integration were measured to determine if they would change over a seven year period as a result of integrated content courses presented to them at the college level. The study was conducted at a major Midwestern university and the population was comprised of preservice teachers who were becoming certified in seventh through twelfth grade mathematics and science, or kindergarten through twelfth grade technology. Six courses were developed over the seven years for the preservice teachers, three were integrated content courses; Mst (math, science, and technology), Smt (science, math, and technology), and Tsm (technology, science, and math), where in each course the first letter stood for the main topic which was supported with content from the other two. In order to measure the attitude and perception change the semantic differential was used (developed by Osgood, Succin & Tannenbaum 1957, cited in Berlin & White, 2012).

A multivariate ANOVA (MANOVA) was applied to the data. The results indicated that as the years went by and new cohorts of students entered the program, their perceptions significantly improved from previous years. All groups also improved in both attitudes and perceptions of these subjects from pretest to posttest. Students started with positive attitudes, but also ended and maintained these positive outlooks. The data also supports the claim that after the courses students found integration to be a more efficient method of presenting information than teaching isolated topics. Data also supported the claim that after the courses students found integration of different disciplines to be a more efficient method of presenting information than teaching isolated topics.

With proper teacher training and professional development, STEM units presented in an inquiry format can help students build and understand their role as 21st century learners. One study reported middle school students in a STEM class determined they were 21st century learners as a result of their use of group work, collaboration and the independence provided to them from the setup of their classes (Prettyman et al., 2012). The purpose of this study was to determine the various perceptions towards learning using laptops in a STEM setting. Each student in this setting was given a laptop to use throughout the day as well as at home. The study took place in a Great Lakes state over the course of one school year, October 2010 to May 2011. Qualitative data in the form of observations and student interviews were gathered to determine how students perceived their learning. The use of computers in this inquiry/STEM environment allowed students to extend their learning beyond the expectations of the class. Students could easily research questions that arose during the inquiry activities, and the questions that arose were diverse and relevant to each student. This allowed students to change their perceptions about themselves as learners, because they were no longer required to learn only information presented to them, but could learn information relevant to their studies and inquiries, producing creators of knowledge, rather than just learners. Students in this study also found the lines between content areas blurring, they saw themselves as problem solvers, who would use resources in all fields to help them make informed decisions, a major component of 21st century skills. To create this type of learning environment teachers had to create project based learning environments, with relevant, real-world problems. Students used various methods to approach the problem, in the end creating unique projects and answers to the problems (Prettyman et al., 2012). The goals of learning environments such as these are to develop the inquiry skills necessary for students to have the opportunity to develop creative thinking skills that can be adapted to the rapidly changing world.

Aside from students being able to think about and solve problems in creative ways through the use of inquiry in STEM settings, students tend to be more satisfied when engaged in these types of classes. In a study conducted by Pawson (2012), 1180 students in their first year of a London university completed a survey to determine their satisfaction in STEM programs. Five hundred eighty-three students were enrolled in STEM courses, while 597 students were in non-STEM courses. The survey used was based on the National Students Survey, developed by the Higher Education Statistics

Agency, and consisted of 22 items. The survey was emailed to the participants, and a variety of statistics were applied to the collected data. To determine which group was more satisfied with their courses a Univariate ANOVA was used and concluded students in STEM courses were significantly more satisfied with their classes than non-STEM students ($F(1, 1174) = 5.86$, $p = .016$).

A meta-analysis of STEM integrated studies was conducted by Becker and Park (2011) to determine what the overall effects of inquiry STEM education were. Relevant databases were searched for STEM studies and 98 studies were identified as fitting to the study. To be included the studies had to be published between 1989 and 2009, and had to be searchable in standard databases including ERIC, digital dissertation, and Google Scholar, and had to include two of the four disciplines of STEM as well as the word integrated. The studies ranged from elementary to college level. Many of the studies utilized a control/experimental group, with STEM being the experimental group. In 33 of these studies effect sizes were found to indicate how effective STEM approaches were compared to the control. Effect sizes (Cohen's *d*) ranged from 3.27 to -0.61, with sizes over 1.0 as a very large effect size. Eight studies had very large effect sizes determining that students in the STEM integrative approach highly outperformed their peers in the control methods. Results of the analysis concluded that engineering tasks may help to diminish gaps for some populations and motivate students to learn math and science. Integrating all four topics provides students with meaningful situations to bridge abstract concepts within these subjects. In most instances experimental groups (STEM groups) outperformed the control groups, and many of these studies had high effect sizes. Integrating STEM subjects had a positive effect on performance and achievement, and these approaches may be better suited to elementary aged students because the evidence suggests students at this age produced better results that in secondary schools. Low effect sizes were shown at the high school and college levels perhaps as a result of testing and the need for specific content, but all students at all schooling levels benefited from integrated approaches.

To create these inquiry experiences in STEM setting for students, teachers need to prepare lessons that not only utilize inquiry skills at various levels, but also incorporate multiple STEM disciplines. Using learning cycles described and teaching models for inquiry are one way to do this. Another format to creating these learning environments is called a mashup (Crippen & Archambault, 2012). A mashup is similar to other inquiry learning lessons. It starts with an essential question which students need to consider and pull prior background for. In order to integrate different STEM disciplines, teachers may consider researching the question using the Internet or various media sources, or create hands-on activities that demonstrate the phenomenon and allow students to add to their prior background. Next students construct a response based on information found through their research using the media or activities completed. Student responses using data can be scaffolded using evidence-claim-reason statements. Then the accepted scientific rationale to the question is presented to students in order for them to compare and contrast their reasoning to the explanation accepted by the scientific community. Lastly, students can share, explain, and defend their rational with the class (Crippen & Archambault, 2012).

Integrating STEM topics focuses on a natural connection between the different disciplines. Engineering is commonly supported with the use of technology (Pieper &

Mentzer, 2013). The engineering design process calls for students to research elements that will help them to reach a solution to the problem they are working on. Through inquiry students research specific details that enable them to create a plan to solve the problem. Even in engineering, inquiry must be scaffolded in order to teach students the appropriate use of computers and the Internet in order to efficiently search for valid information, so as not to waste time searching through content that is not purposeful to the outcome of the project (Pieper & Mentzer, 2013). In a study conducted by Pieper and Mentzer (2013), students in high school engineering classes were presented with a problem to design a playground with materials that could be purchased from local stores. Students had to consider the cost of materials, ADA accessibility, safety, how many kids could be on the equipment at a time, and the setting of the equipment. Senior engineering students in a college setting were given the same problem. All students were given one-to-one access to computers as well as the Internet, and were also given some paper materials with specific information related to ADA laws. All students were given three hours to complete their design.

It was found that participants in the high school setting spent 38.8% of their time accessing information on the internet. Of that percentage of time 26% of that time was spent on print materials, while 74% was spent researching Internet-based sources. In the college setting, students spent 12% of their time researching on the Internet. It was also found that the high school students were less efficient in their searches, finding only 0.3 pieces of information per minute, while the college students found 1.1 pieces of information per minute. It was determined the college students closely mirror the Internet research habits of engineers in the field, while the high school students did not use their time searching the Internet efficiently (Pieper & Mentzer, 2013). The results of the study show a need for teachers to scaffold inquiry in engineering with the use of computers, so students are able to more efficiently use the Internet to research information. Through scaffolding inquiry, and gradually moving students to open-ended inquiry, students will be able research more like engineers in the field.

There is strong evidence in the literature that supports the idea that good teaching does matter. Teachers who have strong content and background knowledge, and who know the underlying principles to present inquiry education are able to more effectively present STEM in classrooms (NRC, 2000). Many national organizations, including the National Science Foundation, National Research Council, the Mathematics Association of America, the National Science Teachers Association, and many others, have recommended changes to preservice math and science teacher education (NRC, 2000). One of the recommendations includes teachers of STEM subjects to get content degrees as well as a teaching degree (NRC, 2000).

Professional Development

It is the job of the teacher to lead students to understanding how inquiry is done in the various fields of science, and in multiple formats. Teachers must teach students the skills necessary to complete inquiry activities that are relevant and meaningful in real-world applications. Leading students from structured activities to more open-ended inquiries allow students to learn the skills associated with inquiry, as well as the multiple formats in which inquiry can be done (Banchi & Bell, 2008). For decades, teachers have engaged students in hands-on activities and treated these alone as inquiry, but these activities more often just serve as supporting activities for students to conduct their own inquiries, and do not create a scientific understanding of the natural world (Clough, 2002; Windschitl et al., 2008). According to the NGSS, students must be able to use and apply the information gleaned from the activities to gather data and create arguments and generate hypotheses about the phenomena presented in the activities. By themselves, these isolated activities do not help students to learn science (Clough, 2002; Windschitl, 2008). As a result, adequate and continual professional development must be provided to educators to prepare them to teach inquiry science and the NGSS.

Professional development is traditionally conducted from outside sources including university personnel, professional development program leaders, informal science education leaders, and others (The National Academies of Sciences, Engineering, and Medicine, 2015). Professional development tends to take place away from the educator’s school site or out of contract time.

Standards for science teachers were originally written into the NSES. Being placed before the content standards, they were presented as the necessary base to promote science education. The standards for science teachers were grounded in the assumptions that change was needed throughout the entire system, not just in science teacher education; “what students learn is greatly influenced by how they are taught. The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned. Student understanding is actively constructed through individual and social processes. Actions of teachers are deeply influenced by their understanding and relationships with students.” (NRC, 1996, P. 27). These assumptions guided the development of professional development standards for science teachers. The NSES note becoming an effective science teacher requires teachers to engage in continual learning from preservice to the end of their professional careers (NRC, 1996). Effective professional development leads to changes in knowledge, teacher practice, and student achievement (Desimone, 2009) supporting the need to increase the quality of professional development for inservice science teachers.

Science education reflects rapidly changing knowledge, and as a result, teachers must undergo continued training to facilitate their understanding of science as inquiry rather than a body of facts to be memorized. Professional development for science teachers mirrors professional development in other areas. First, it is a continual, lifelong process. With the ever-changing body of literature supporting how students learn in multiple ways, teachers must adapt their pedagogical content knowledge to best fit current research on how students learn. Teacher education programs as well must make an effort to give preservice teachers access to actively participate in school science programs and mirroring the professional development that would be experienced by inservice teachers (NRC, 1996).

As well as being a continual process over the course of a teacher's career, professional development should be of sufficient duration to develop intellectual and pedagogical change (Desimone, 2009; National Academies of Sciences, Engineering, and Medicine, 2015; NRC, 1996). Research suggests professional development that includes intensive training as well as follow up trainings throughout a semester or school year increase the chance that a teacher will make systematic changes in their teaching approaches (Desimone, 2009). In science education, many are still making the pedagogical shift to inquiry teaching. Prolonged trainings incorporating active learning opportunities in inquiry processes will enable teachers to learn essential science content as well as gain insight into the nature of science (Desimone, 2009; National Academies of Sciences, Engineering, and Medicine, 2015; NRC, 1996). Presenting active learning opportunities over time will increase the likelihood that the teacher will make instructional shifts to integrate the knowledge of science and pedagogy while teaching science.

Another important component of professional development includes a strong content focus. Research suggests a link between student achievement and increases in teacher subject matter knowledge gained through activities from professional development (Desimone, 2009; National Academies of Sciences, Engineering, and Medicine, 2015). The NSES professional development standards indicate teachers must learn essential science content through the lens of inquiry to develop increased student achievement (NRC, 1996). Focus should surround fundamental facts, as well as conceptual connections, and the nature of science inquiry (NRC, 1996).

Both Desimone (2009) and the NSES (1996) promote a need for professional development to be coherent between the school, district, state, and nation. Research has suggested the most effective professional development for science teachers should align with local districts policies and vision (National Academies of Sciences, Engineering, and Medicine, 2015). Clear goals should be established and organized to develop understanding over time. Courses and workshops should support the same goals and focus efforts to achieve those goals (NRC, 1996). Alignment from preservice courses to inservice teacher trainings is needed to ensure professional development opportunities are maximally useful for teachers (NRC, 1996).

The success of professional development is contingent upon dynamics of a school and district. Climate, and the ability to take risks or change the structures set up within a school are required to promote systematic change. Therefore, providing administrators and teacher trainers in professional development is important to ensure teachers are supported (NRC, 1996). This collective participation encourages interaction with educators and administrators and can be a powerful form of learning (Desimone, 2009).

Assessment of Inquiry STEM Programs

One goal of STEM education is to create students with twenty-first century learning skills (Prettyman et al., 2012). Learning how to engage in open-inquiry has been proven to develop these skills in students (Becker & Park, 2011). In order to create this type of students, teachers must scaffold inquiry from teacher directed to open ended in order to ensure students are engaging in appropriate inquiry based activities that are meaningful to future careers. Specific levels of inquiry must be measured to identify the level of proficiency with inquiry students are able to complete in order to determine what inquiry aspects students are missing and where teachers need to guide their inquiry instruction in the future. Classroom features, and student knowledge assessments vary in their effectiveness.

Many protocols have been used to assess inquiry and STEM content in a classroom. The most commonly used is the Reformed Teaching Observation Protocol (RTOP; Sawada et al., 2000). The RTOP was the result of the need to define and measure reform in classrooms using an instrument with a student-centered focus. The authors define reform based on literature from Anderson, Anderson, Vaerank-Martin, Romagnano, Bielenberg, Flory, Mieras and Whitworth (1994) who describe reform as the movement away from traditional didactic teaching towards more student-centered, problem-solving approaches. The RTOP was designed to measure the reformed instructional practices of teachers, but does not focus specifically on inquiry and inquiry skills (Marshall, Smart, & Horton, 2009). A limiting factor to the RTOP is its use of a Likert scale to identify levels of reform. Marshall et al. explain this makes it difficult to describe what improvements are needed to meet the requirements for the next step up on the Likert scale (2009).

Another instrument designed to assess inquiry-based instruction is the Equip, created by Marshall et al. in 2009. The design of the instrument allows it to measure how effective teachers are with presenting standards-based and inquiry-based learning, specifically in science and mathematics. A major difference between the Equip protocol and many others is it focuses specifically on inquiry based instruction whereas others tend to focus on overall quality of instruction (Marshall et al., 2009). A major flaw in the design of this instrument is inquiry research has historically been focused on science education, and very little research has been conducted on mathematics inquiry. As a result, the development of the instrument pulled strongly from the literature on scientific inquiry, and less on mathematics inquiry (Marshall et al., 2009). A benefit of the Equip protocol over many others is its use of a descriptive rubric to describe the effectiveness of inquiry in science and mathematics settings (Marshall, 2009). Many other protocols described rely only on a Likert scale (Sawada et al., 2000).

Some instruments used today have more of a focus on the content rather than just the teaching practices. For example, the Science and Engineering Classroom Learning Observation Protocol (SEcLO; Dringenberg, Wertz & Purzer, 2012) was created to identify the connection between learning outcomes in engineering and science, and teaching practices. This protocol was specifically created with the kindergarten through twelfth classroom in mind, and specifically focuses on the engineering practices used in classrooms and how those practices create successful learning outcomes. The SEcLO was created by reviewing the literature on engineering education, and looking at the content in commonly used engineering programs such as Engineering is Elementary and Project Lead the Way. Other commonly used protocols served as models to help the authors create the instrument, including the RTOP. After looking through the literature and common assessments the authors determined which items would be included on the protocol, tested those items and then revised them until they fit the need of assessing the connection between learning outcomes and engineering practices (Dringenberg et al., 2012). Since the SEcLO only measures learning outcomes based on engineering practices it leaves room to look at other STEM areas and inquiry practices related to learning outcomes.

Assessing a student's ability to do inquiry is just as hard as determining how to teach inquiry. The NSES states conventional paper and pencil tests commonly only assess content knowledge, which commonly consists of memorized facts, do not meet the needs of assessing a student's ability to do inquiry (NRC, 2000). Inquiry assessments need to include what each student knows about, and their ability to develop, questioning, explanations, design and conduct investigations, and use data as evidence to support explanations (NRC, 2000). How these should be assessed is under debate. Multiple choice and true/false tests typically don't require students to think too deeply in to the content, but they are fast and don't require much interpretation. One the other end of the assessment spectrum are investigations, reports and projects. These take days, weeks, or even months to finish but allow for lots of feedback and insight into the student's thinking. Unfortunately, these assessments are very subjective, what one person may think the student knows may not be what another person thinks the student knows based on evidence provided by the investigation (NRC, 2000).

In addition to evaluating the level and quality of inquiry students are engaging in within a program, it is also important to consider how student interests are impacted as a result of participating in the program. The STEM Semantics Survey (Tyler-Wood et al., 2010) utilizes a Likert Style questionnaire to measure middle and high school students' interest in science, math, engineering, technology, and careers in STEM. The STEM Semantics Survey was developed through an NSF ITEST grant Middle Schoolers Out to Save the World (MSOSW) between 2008 and 2011. Internal consistency for each section of the assessment range from $a = 0.84$ to $a = 0.93$ and are within the very good to excellent range (Tyler-Wood et al., 2010).

Another consideration when evaluating the effectiveness of an inquiry STEM program, is how the teacher attitudes towards their own teaching abilities are affected. The Science Teacher Efficacy and Beliefs Instrument (STEBI-A) created by Enochs and Riggs (1990) measures just that. This instrument includes 25 Likert type items to determine inservice teachers' beliefs towards science instruction and learning. The instrument measures two aspects, self-efficacy and outcome expectancy. The STEBI-A is a commonly used self-efficacy instrument with a reliability of $a = 0.92$ for the self-efficacy portion of the instrument and $a = 0.91$ for the outcome expectancy portion of the instrument, both in the very high range.

Due to the three-dimensional nature of the NGSS, new assessments need to be created incorporating all three dimensions into the assessment. Current assessments tend to assess only one dimension, the DCI, and not SEP or CC. The major challenge facing assessment designers is how to support and determine student proficiency along the "intertwined dimensions" (NRC, 2014, p. 29). To support the established three-dimensional learning in the NGSS, curriculum, instruction, and assessment have to integrate every dimension (NRC, 2014). Assessment developers must be able to structure performance tasks utilizing scoring rubrics to assess understanding of students' level of mastery of performance expectations for each grade level (NRC, 2014). An additional challenge to assessing the NGSS is the emphasis placed on how the standards increase in sophistication over time, so assessments must be able to pin point the level a student has reached along a continuum for the entire kindergarten through twelfth grade period (NRC, 2014). Traditional assessments measure if a student has mastered content for a certain grade level, creating a shift in how to structure science assessment tasks (NRC, 2014).

Summary

Inquiry has served as the base to construct scientific literacy in integrated STEM programs. The NGSS serve to focus core ideas, practices, and crosscutting concepts into performance expectations that can be woven into STEM curricula and programs. Implementation of these programs utilizing inquiry techniques can lead to greater interests in STEM fields. However, adequate professional development must be employed to ensure teachers have the ability to implement these programs in classrooms in a way that will allow for increased student engagement, hopefully creating greater interests in STEM while developing a deeper understanding of the content.

Chapter Three: Method

Although there were many goals and objectives outlined in Project ReCharge, the current research focuses on the effectiveness of the program in relation to the research questions:

1. Does student content knowledge change as measured by pretest/posttest multiple choice content data?

   H_0: No differences exist between pretest and posttest data.

   H_1: Significant differences between pretest and posttest data exist

2. Do student attitudes towards STEM subjects and careers change as measured by the STEM Semantics Survey (Tyler-Wood et al., 2010)?

   H_0: Student interest towards STEM subjects and careers does not change.

   H_1: Student interest towards STEM subjects and careers changes.

3. Does teachers' self-efficacy in science education change as measured by the STEBI-A (Enochs & Riggs, 1990)?

   H_0: Teachers' self-efficacy in science education does not change.

   H_1: Teachers' self-efficacy in science education significantly changes.

4. Does teacher content knowledge change as measured by a multiple-choice content test?

   H_0: Teachers' content knowledge does not change.

   H_1: Teachers' content knowledge significantly changes.

To answer these questions, quantitative data were collected for each year of the grant and were analyzed using parametric and non-parametric statistical analyses, as described below. The research design used an experimental group only for each research question.

The implementation of the curriculum itself, as well as the intensive and continuing professional development are considered dependent variables that were manipulated to determine if statistical differences exist, in which the independent variables of STEM interest, content knowledge, and teacher efficacy would be a result of the implementation of the curriculum.

Grant Specifics

Project ReCharge was funded by the National Science Foundation, Innovative Technology Experiences for Students and Teachers (ITEST) division. The project was funded for three years, from August 2014 to July 2017. A partnership between the University of Nevada, Reno and local nonprofit energy group, Envirolution. During the three years, the project focused on accomplishing the following goals and objectives:

Goal 1: Over three yearly implementation cycles, Envirolution will expand and enhance authentic STEM learning experiences for northern Nevada middle and high school students through interaction with real-time school electrical consumption data utilizing ICT tools.

Objectives:

1. Expand implementation of real-time data interfaces for students, teachers, and facilities managers to track end-use energy consumption.

2. Enhance Project ReCharge energy efficiency curriculum for varied implementation through 8th grade math and science, high school environmental science and CTE classes.

3. Implement curriculum in five middle schools and five high schools in both economically disadvantaged and rural communities.

4. Conduct evaluation to assess impacts of the project on teachers, students and school facilities and refine the project implementation through each annual cycle.

5. Increase academic content knowledge in energy and energy efficiency for participating students.

Goal 2: Envirolution and UNR will improve STEM and ICT competence with at least 30 teachers through interactive professional development workshops focused on energy efficiency.

Objectives:

1. Improve teacher content knowledge and competence in STEM curriculum pertaining to energy.

2. Provide training on the Project ReCharge STEM classroom program.

3. Provide STEM materials and resources.

4. Enhance educator comfort and performance in the teaching of inquiry-based curriculum.

Goal 3: Project ReCharge-trained teachers and Envirolution support staff will engage over 2,500 students in the STEM service-learning program, which in turn assist school district facility managers and contractors to reduce energy costs over 10% while maintaining or improving building comfort for students and teachers.

Objectives:

1. Integration of Load IQ energy monitors (or equivalent) and existing Building Control Services control systems to monitor electrical usage and building performance.

2. Students and facilities staff identify and present potential energy saving

solutions.

3. Implementation of energy efficiency solutions and behavioral changes.

4. Student monitoring of the decrease in energy usage and costs.

5. Student calculations of school's reduction of carbon footprint.

6. Students and professionals analyze data over time to measure and verify savings.

Beginning in August 2014, a partnership between local nonprofit Envirolution and the University of Nevada, Reno's Raggio Research Center was established, and a project team was created to fulfill the requirements of the grant. The team met at the beginning of the first year of implementation, October 2014, and determined several items that needed to be addressed prior to school and teacher selection. First, a team including members from both Envirolution and the University of Nevada, Reno was established to create and refine a curriculum. After which Envirolution could purchase materials needed to implement the curriculum. Researchers from the University were charged with identifying and creating assessments to measure the goals and objectives of the project, and planning professional development. While these tasks were being undertaken by assigned groups, Envirolution began meeting with Washoe County School District to determine appropriate schools and teachers to recruit.

Furthermore, LoadIQ energy monitoring hardware needed to be installed in selected schools, requiring navigation through appropriate channels within the school district headed by the technology experts from Envirolution and LoadIQ. The student dashboard used by students to monitor electrical loads within their school still needed to be established and refined through alpha and beta testing by the first-year participants. These tasks too several months spread over the first year to complete.

Curriculum Development

Prior to developing a curriculum, research surrounding inquiry instruction, STEM programs, NGSS, and professional development was conducted. This allowed team members to develop a scope and sequence for standards and standard bundles that would be addressed throughout the five-unit curriculum. The utilization of Rodger Bybee's BSCS 5E Instructional Model (Bybee, 2002) was established as the format for all lesson plans. Additionally, a structure allowing teachers to move from more to less structured inquiry formats was deemed important, so while the first units utilize more teacher-led inquiry structures, unit five presents open-ended inquiry opportunities for students to explore, with the hope of developing scientific habits of mind while participating in the project. The curriculum team consisted of Researchers from the University who provided direction for lessons and inquiry practices, and staff from Envirolution who were charged with formatting and writing established and agreed upon lessons into the 5E (Bybee, 2002) format.

The program was designed for implementation in middle and high schools. The DCIs of physical science and engineering were the focus throughout the curriculum, incorporating all of the eight Science and Engineering Practice and Crosscutting Concepts outlined in the NGSS. The middle schools in the district utilize an integrated science program, allowing for any teacher in selected schools to implement the curriculum. However, local high schools are still subject specific, requiring volunteers to teach Environmental Science courses or Career and Technical Education courses.

After studying the middle and high school NGSS standards and establishing goals for the curriculum, a scope and sequence of lessons was established. Benchmarks for the curriculum included developing background in energy and energy generation, moving through energy uses within buildings including lighting, heating/cooling, and appliances, energy monitoring with the use of LoadIQ hardware and software, and finally student proposals for reducing energy costs. Starting with activities created through a partnership between the Desert Research Institute and NV Energy, Envirolution's "Green Box" lessons and materials served as the starting point for the Project ReCharge curriculum. Although the lessons from the Green Box program were established with student handouts and teacher materials, they were not a complete curriculum, but rather a set of activities teachers could check out and incorporate into their classrooms. These lessons covered two major themes: (1) Thermal Systems including water heating, building envelopes, passive heating and cooling, and (2) Electrical Systems including lighting, appliances, and how to analyze home energy bills. These lessons were written into a 5E lesson cycle with additional teacher background information and student handouts created to fit the needs of the Project ReCharge goals.

The curriculum team also determined that although the modified Green Box lessons would be required to utilize the LoadIQ energy monitoring software and analyze the collected data appropriately, they were not enough to give students a complete understanding of the basics of electricity and electrical generation. More background knowledge would be required for students to appropriately apply their knowledge to making energy saving projects. Curriculum on electricity and electrical generation has been developed by many companies. Lessons from the Full Options Science Systems

(FOSS) electricity kit were adapted to fit within the ReCharge curriculum and would serve to build background knowledge in simple circuits, series and parallel circuits, and conductivity. Activities from FOSS were adapted to fit into the BSCS 5E Instructional Model (Bybee, 2002) with appropriate explanation of energy and attention to each dimension of the NGSS made explicit throughout the lessons.

Additional lessons on electrical generation were created using ideas from KidWinds wind turbine kits, and solar energy kits, as well as developing lessons on electromagnetic induction. These lessons became Unit One, which develop the background knowledge required for students to engage in the lessons from the Green Boxes program. Modified lessons from the Green Boxes became Units Two and Three.

Once Units One through Three were completed, required lessons were established and optional lessons were included that would serve as additional background and enrichment lessons for the teachers to use if and when needed. The required lessons in these units served as the background knowledge required for students to interact with the LoadIQ student dashboard, and make proposals for energy savings within their school.

Prior to the first year of the NSF grant, the LoadIQ hardware had been installed in one middle school and one high school from a previous grant. However, the web-based student dashboard was still being developed and tested, and was not ready until the project's second year of implementation. Unit Four of the curriculum would include lessons focusing on data collection and analyses based on the real-time data gathered from lighting and appliances within the school through the LoadIQ hardware. The schools who had LoadIQ technology installed from the previous grant served as pilot schools in year one to test out the hardware and web-based student dashboard. As a result of the beta testing required to ensure the student friendly nature of the dashboard, Unit Four was developed in year one but required refinements well into the second year of the project.

Once the dashboard was approved and finalized in the second year of implementation, the lessons for Unit Four were established, include exploring outliers and correlations, energy trends, classroom lighting and appliance analyses, and school HVAC analyses. These lessons require students to use the dashboard to analyze various loads in real-time, and identify trends to make claims about energy usage at their school. These claims would allow students to make proposals that would ultimately save their school costs on their energy bills. The proposal process became Unit Five of the curriculum and was finalized in the second year of the project. Student groups or classes would make a proposal including a mission statement, statement of need, goals and objectives, project activities, data collection, cost share, and impact analysis. Completing the proposal requires students to apply knowledge learned from Units One through Three and support their proposed changes with data analyzed using the web-based student dashboard in Unit Four. The curriculum map with all five units and lessons can be found in Appendix A.

Project ReCharge Assessments and Statistical Analyses

To determine the effectiveness of the program and determine if the project met the goals outlined, several student and teacher assessments were used to collect quantitative data. The assessment and evaluation team consisted of researchers from the University of Nevada, Reno, who maintained IRB procedures consistent with the University. A content test covering Units One through Three was created and administered to participating teachers and students in each year of the project. Additionally, a STEM Semantics Survey (Tyler-Wood et al., 2010) was administered to students only to determine if changes in student interest existed after participation in the program. Teacher assessments also included Science Teachers Efficacy and Beliefs Instrument for In-service teachers (Enochs & Riggs, 1990). All assessment data were Likert style, or selected-response. Only members of the research team had access to the data which were coded and stored in order to be analyzed at the end of each year.

Content test.

Research question one and research question two are aligned to goal one and goal two of the grant. Goal one objective five and goal two objective one require the project to increase academic content knowledge in energy and energy efficiency for participating students and teachers. To determine if this goal was met a forty question, selected-response content test was created for Unit One through Unit Three between October 2014 and January 2015, prior to the first year of implementation. Face validity was established by energy professionals from Envirolution who verified content accuracy and ensured the content assessed was taught in the required lessons.

In January 2015, students from one high school environmental science class participated in a trial run of Units One through Three. Students were given a pretest and posttest content assessment prior to the official roll out of the program in order to work out any issues. An item analysis was applied to the resulting content test data, and questions with an item difficulty less than .20 or greater than .80 were eliminated (Sprinthall, 2012). Additionally, if the discrimination index for the item was negative that item was also eliminated (Sprinthall, 2012). Additional items were added and checked for validity to equal a total of forty questions.

After the first year of implementation, results from the content test and feedback from participating teachers suggested the research team to shorten the content assessment to thirty questions. An item analysis was conducted again on the data collected from all students and teachers from year one and an additional ten items were eliminated based on the criteria from the first item analysis. The second and third years both used this thirty-question content test so data could be compared from pretest to posttest, and from year two to year three results.

STEM semantics survey.

Research question two is also aligned with goal one of the grant. In addition to increasing academic content knowledge, Goal one objective four required an evaluation to assess the impacts of the project on teachers and students. To determine if student attitudes towards STEM subjects and careers changed as a result of participation in the project, the STEM Semantics Survey (Tyler-wood et al., 2010) was given as a pretest and posttest. Students from year one were given paper copies of the assessment and student participants from years two and three took the assessment online via SurveyMonkey.com. The STEM Semantics Survey was developed through an NSF ITEST grant Middle Schoolers Out to Save the World (MSOSW) between 2008 and 2011. Internal consistency for each section of the assessment range from $a = 0.84$ to $a = 0.93$ and are within the very good to excellent range.

Science teacher self-efficacy and beliefs instrument (STEBI-A).

Research question three focuses on impacts to teachers' self-efficacy. To determine the impacts of the project on teachers' self-efficacy and beliefs about science the STEBI-A (Enochs & Riggs, 1990) was administered to each year's participating and returning teachers. This instrument includes 25 Likert type items to determine inservice teachers' beliefs towards science instruction and learning. The instrument measures two aspects, self-efficacy and outcome expectancy. The STEBI-A is a commonly used self-efficacy instrument with a reliability of $a = 0.92$ for the self-efficacy portion of the instrument and $a = 0.91$ for the outcome expectancy portion of the instrument, both in the very high range.

Participants

Per grant requirements, a minimum of ten schools, thirty teachers, and 3,000 students were included in the grant over the three years. The number of teacher and student participants over the three years exceeded the minimum requirements of the grant.

School selection.

The curriculum was implemented in schools with disadvantaged populations, specifically low-income students and high minority schools. Schools were selected based on input from the district as well as approval from the principal of each school. Meetings with the local school district, members of Envirolution and the University of Nevada, Reno were held to determine which schools met the requirements. Envirolution took the role of recruiting schools and teachers after these meetings, giving out information about the program and benefits for teacher participants.

As per grant requirements, over the course of the three years the project needed to be implemented in ten schools. The schools were suggested during initial meetings with the school district and a progression of when to implement at which school site was determined. Less schools were included in the first year to work out any problems that would arise. The first year of implementation hosted two schools, one middle and one high school, for a total of two schools. Year two of the project included the two schools from year one as well as an additional five new school sites, two middle schools and three high schools, for a total of seven schools. Year three added four additional schools, three middle schools and one high school were added to the returning schools of year two for a total of eleven schools over the three years of the grant. Of the eleven participating school sites, six were middle schools and five were high schools. Demographics for each school site can be found in Appendix B.

Teacher selection.

Once the schools were selected, teachers were recruited and volunteers were accepted into the program. Recruitment for year one occurred between November 2014 and February 2015 so professional development could occur during the teachers' spring break. Recruitment for years two and three occurred in May of the previous year of implementation so that professional development could occur over the summer break. Educators teaching middle school science and high school environmental sciences, math, and Career and Technical Education classes were given priority for acceptance into the program. Participating in the program required teachers to implement required lessons in Unit One through Unit Five within one academic year. Year one used a shortened timeline, requiring lessons to be completed in the last quarter of the school year.

However, year one teachers did not have a complete Unit Four or Unit Five to implement. The curriculum does not need to be taught in isolation, but rather woven into their classes throughout the semester. Participating teachers must also administer the content test and the STEM Semantics Survey (Tyler-Wood et al., 2010) to students at the beginning and end of Unit One through Unit Three, and return tests to the research team for analysis.

Requirements for professional development include completing forty-five hours of professional development training. This included three days of intensive professional development during spring break (April 2015), for year one participants, or four days of intensive professional development in the summer (July 2015 or July 2016), for participants in year two and year three. Eight two-hour follow-up sessions occurred once a month and were spread throughout the remainder of the school year. The remaining thirteen hours teachers met informally with the Project ReCharge team and other teachers in the program to discuss the curriculum and discuss implementation.

Participating teachers received a $1000 stipend or three graduate credits at the completion of the forty-five professional development hours. Along with the curriculum and stipend or credits, teachers also receive material bins and supplies needed to implement the curriculum totaling around $2,100. Each participating school also received twenty Chromebooks to access the student dashboard required to analyze data collected at the school site. Participating teachers had the option of continuing in the next year of the project and receiving the same benefits as long as they completed the same requirements. Teachers could opt out at any time but would not receive the stipend or three graduate credits.

Teacher Participants

A total of 47 teachers participated in the project over the of three years. Fourteen of the teachers participated for more than one year, whereas thirty-three participated for only one year. The first year had five total teachers. Year two had a total of twenty-two teachers one of whom was a returning teacher from year one. The third and final year of implementation had thirty-six teachers with thirteen returning from year two, providing twenty-three new teachers in year three.

Five teachers participated in the first year of implementation. Three teachers identified as male and two as female. Four teachers held a Master’s degree and one held a Bachelor’s degree. Three of the teachers had been teaching more than five years and two had been teaching less than five years. All participants identified as white. One teacher continued into the second year of the project.

Year two hosted one returning teacher from year one as well as an additional twenty-one teachers. Twelve of the year two teachers taught at the middle school level, while ten taught at the high school level. Eleven teachers identified as male and eleven identified as female. Thirteen of the year two teachers signed up to participate again in year three, and an additional twenty-one teachers were brought on in year three for a total of thirty-four participating teachers in year three. Of the total year three teachers twenty-one taught in middle school and twelve taught in high school. One participant was a district trainer. Additionally, fourteen were male and twenty were female.

				Grade			Sex	
	Total	Returning	New	M	H	D	M	F

Year 1	5	0	5	3	2	0	3	2
Year 2	22	1	21	12	10	0	11	11
Year 3	34	13	21	21	12	1	14	20

Note. Grades are middle (M), High (H), or District Trainer (D).

Student Participants

Over the three years of implementation, a minimum of 3,000 students are required to participate in the program. The number of student participants purposefully increased from year one to year three. By the end of the program, 4,123 students participated in a classroom where Project ReCharge was being implemented under the structures set up for the grant.

Year one.

Data were collected for 501 students in the first year of implementation. The population included 166 males, 158 females, and 177 unidentified students total. The majority of students were in tenth grade (n = 176) while eighth grade had 60 students, ninth grade had only three students, eleventh grade had 74 students, and twelfth had ten students. The students self-identified for race from the identifiers the school district uses and included one American Indian, twenty-three as Asian, twenty-two as black, 115 as Hispanic, one as pacific islander, 211 as white, nine as other, and 119 with no identification.

Year two.

Data were collected and analyzed on 1224 students in year two. Of the population 555 were female, 647 were male, and 20 unidentified. This population included 448 students from grade seven, 387 from eighth grade, 71 from ninth grade, 52 from tenth grade, 183 from eleventh grade, 64 from twelfth grade, and twelve unidentified students.

Eighteen of the students identified as American Indian, 61 as Asian, 27 as Black, 409 as Hispanic, 628 as White, 33 as other, and 41 were unidentified.

Year three.

The third year of implementation included the greatest number of student participants at 2,398 total. Of that population 1,096 were female, 1,285 were male, and fourteen were unidentified. This year included sixth grade students for the first time with 218 participants. Seventh grade included 716, eighth grade had 925, tenth grade accounted for 256 students, eleventh included 56 students, twelfth had 21, and eleven students were unidentified. The race breakdown for the third-year students included 921 white, 895 Hispanic, 63 Black, four American Indian, 101 Asian, 289 multi-race, and 83 unidentified. Student demographics in tabular format can be found in Appendix B, Table 2 and Table 3.

Statistical Analyses

Student data.

Students were administered both the content test and the STEM Semantics Survey (Tyler-Wood et al., 2010) two times during each year of implementation in a pretest/posttest manner. The pretest was given prior to any instruction in the Project ReCharge Curriculum, and the posttest was given at the end of Unit Three. Student data for year one, year two, and year three were analyzed separately and were analyzed all together to determine changes to the project overall. Data from middle school and high school were analyzed separately for each year of implementation.

To analyze yearly student data collected from the content test, data were coded and paired for each student. A power analysis was conducted prior to data analysis and it was determined a sample of fifty-four was needed to maintain a power of 0.95 with an effect size of *d* = 0.5. The STEM Semantics Survey resulted in Likert-style data. As a result, the data did not meet the requirements to utilize a parametric analysis and instead a Wilcoxon Matched Pairs, Signed Ranks test was used due to the data being ordinal.

Content test data were then combined for the three years of implementation and a paired samples *t*-test was applied to the data to determine if changes to student knowledge changed over the course of the program as a whole. Additionally, data for all three years of the STEM Semantics Survey were analyzed using a Mann-Whitney U to determine if changes to student interest in STEM subjects and careers changed in the program.

Teacher data.

Due to the timeline for year one being shorter than years two and three, only two administrations of each the content test, and STEBI-A (Enochs & Riggs, 1990) were given to teacher participants. A power analysis was conducted prior to data collection in year one. It was determined a sample size of 45 was needed to maintain a power of 0.95 with an alpha of 0.05 and an effect size of 0.5 when running a paired-samples *t*-test. The assumptions of a parametric analysis could not be met with sample size of five. Therefore, a Wilcoxon Matched Pairs, Signed Ranks Tests was used to analyze the data. This analysis was deemed appropriate due to the ordinal data collected from the STEBI-A as well as the small sample size (*n* = 5) and paired data collected for all three assessments (Sprinthall, 2012).

Years two and three allowed for three administrations of each assessment to be given to teachers. A power analysis was completed prior to data collection and it was concluded that a sample of 43 was needed to maintain a power of 0.95 with an effect size of 0.25 when running a repeated-measures, within-subjects ANOVA. As with the first year of the project, a small teacher sample size as well as the ordinal data collected for two of the three assessments meant parametric assumptions could not be met. Therefore, a Friedman Two-Way Analysis of Variance (ANOVA) by Ranks was used to determine if differences in the data exist. The Friedman ANOVA by Ranks could be applied to matched ordinal data with a small sample size (Sprinthall, 2012).

Year one teachers took the pretest for all three assessments before beginning the intensive professional development during spring break and again in May 2015. Teachers participating in years two and three were given the pretests at the beginning of the intensive summer PD, the posttests at the end of the fall semester in December, and the post posttests at the end of the spring semester in May of their year of participation.

Experimental Design and Variable Manipulation

The research utilizes a quasi-experimental design. Teacher participants were not randomly selected, but were volunteers recruited based on school district input and principal agreement. Additionally, students were not selected randomly, but were involved in the project due to teacher participation. Additionally, no control group which makes causality of the statistical analyses harder to determine. The implementation of the Project ReCharge curriculum in the classroom serves as the independent variable in the study. Results of the content test, STEM Semantics Survey, and STEBI-A are the dependent variables, resulting from the use of the curriculum in the classroom.

Procedure

The first population of students and teachers in the study began instruction with the Project ReCharge curriculum in 2015. After the curriculum and assessments had been created, and the LoadIQ hardware had been installed in selected schools, the five volunteer teachers in year one underwent their two-day intensive professional development during spring break in April 2015. Participants were given the teacher assessments via surveymonkey during the first day of the professional development. At the end of the intensive professional development, teachers received bins of materials to use in their implementation of the program. Teachers took materials and the curriculum binders back to their classrooms to begin instruction. Before any instruction took place, teachers gave paper copies of the student content test and STEM Semantics Survey (Tyler-Wood et al., 2010) to the classes where the curriculum would be implemented. Since the project was being implemented as part of the classes regular curriculum, there was no opt out option for students.

After the pretests were given to the research team implementation of the lessons could begin. Teachers integrated the curriculum into their classes in different ways. Some taught the Project ReCharge curriculum exclusively and others integrated the required lessons into their own units and lessons. After Units One through Three were completed teachers were again required to give their students the post content test and post STEM Semantics Survey (Tyler-Wood et al., 2010). Teachers were required to complete the first three units as well as give the posttests to their students no later than June 1, 2015. Teachers were also given the content test and STEBI-A (Enochs & Riggs, 1990) again via surveymonkey.com. The assessments were made available for teachers in mid-May, and also had to be completed no later than June 1, 2015. Data for the first year of implementation could then be analyzed. Changes were made to the content test, reducing the number of questions from forty to thirty.

In May 2015, Envirolution began recruiting teachers for the second year of the project. Selected teachers went through am intensive professional development the last week of June 2015. Teacher participants spent the first hour taking the content and STEBI-A (Enochs & Riggs, 1990) pretests. Teachers were given their materials and curriculum binders at the professional development which they could take and implement in their classrooms as they saw fit, so long as they implemented the entire five-unit curriculum by June 1, 2016. Teachers were asked to give the pretests to students at the beginning of the school year, and immediately following Unit Three. Some teachers did not implement the curriculum until the second semester, and gave pretests out in January 2016 instead of August 2015. Student assessments for year two were loaded onto surveymonkey.com allowing teachers to administer the assessments whenever they saw fit rather than having to request paper copies which would take several days to copy and get delivered.

Teachers met with the Project ReCharge team members monthly between August 2015 and May 2016 to fulfill professional development requirements. During these meetings, more time was spent on the curriculum implementation and inquiry approaches as well as the LoadIQ hardware and student dashboard utilized in Units Four and Five. In November 2015 teachers received their second administration of the content test, and STEBI-A (Enochs & Riggs, 1990) via surveymonkey.com, and all teachers received their third and final administration of the assessments in May 2016. All assessments for teachers and students were required to be completed by June first for analysis and reporting.

Year three ran on the same timeline of events as year two. Recruitment of new teachers began in May 2016. The summer intensive professional development took place the last week of July 2016. Teachers returned to their classrooms in August 2016 and gave the pretests to students, after which they implemented the curriculum and were asked to give posttests after the completion of Unit Three. The posttests for teacher assessments were administered on surveymonkey.com in November 2016 and the post posttests were given in May 2017. All student posttests were due by June 1, 2017 for analysis and reporting purposes. A project timeline can be found in Appendix C.

Chapter Four: Results

This section includes data analyses for all three years of the grant. Data are separated by research question. Student content test data were analyzed using a two-tailed, paired samples *t*-test. A power analysis was conducted prior to running a paired samples *t*-test, requiring a sample size of 54 students to maintain a power of 0.95 with a medium effect size of 0.5. Data for the STEM Semantics Survey (Tyler-Wood et al., 2010) were analyzed using a Wilcoxon Matched Pairs, Signed Ranks analysis due to the ordinal data collected. To maintain a power of 0.95 with a medium effect size of 0.5, a total sample size of 57 would be needed. Every year of the grant the student population exceeded the sample size required to analyze the data using parametric and nonparametric analyses. At the completion of the grant, data from all three years were analyzed together as well as disaggregated for middle school and high school analyses to gain understanding about the overall effectiveness of the grant.

Teacher participants from year one only received two administrations of each assessment. The sample size needed to maintain a power of 0.95 with a medium effect size of 0.5 was 54 in order to run a two-tailed, paired-samples *t*-test. As a result of the small sample size ($N = 5$) for year one, Wilcoxon Matched Pairs, Signed Ranks analysis was applied to each of the three assessments. Using a nonparametric assessment in year one allowed for analysis of the STEBI-A as well due to the ordinal nature of the data. Teachers in the second and third years of the grant were required to take three administrations of each assessment; content test, and STEBI-A. When using a repeated measures ANOVA, to maintain a medium effect size of $\eta^2 = 0.25$, with an alpha = 0.05 a sample size of 43 would be needed. In no one year of the grant did the teacher population meet this requirement. As a result, nonparametric statistical analyses were applied to the yearly teacher data. At the end of the three years of the grant, all teacher participants from all years were analyzed together using an ANOVA for the STEBI-A because the population of all three years was greater than 43.

For all analyses, effect sizes are reported. Cohen's *d* is used for *t*-test analyses. A small effect size using *d* is 0.20, a medium effect size is 0.50, and a large effect size is 0.08. The Analysis of Variance tests utilized the eta square (η^2) statistic for effect size. The value for a small effect size using era square is 0.01, a medium effect size is 0.06, and a large effect size is 0.14.

Question One

Question one analyzes data collected from a multiple-choice content assessment to determine if changes to student content knowledge were found in the area of energy efficiency. The null hypothesis assumes no differences exist in student content knowledge between pretest and posttest.

Year one.

Year one consisted of 501 students and five classes. However, data for only two high school classes were analyzed, totaling 179 students. Participants with missing or incomplete data were eliminated from the analysis. Students were given the content pretest created for the first year of Project ReCharge, consisting of 40 questions, in April of 2015, and the posttests after teaching Unit 3, but no later than June 1, 2015. A post hoc power analysis was conducted resulting in a power of 0.99 with an alpha of 0.05 and an effect size of 0.5 using the given sample of students. A two-tailed, paired samples *t*-test was applied to the data to determine if students' content knowledge changed as a result of participating in the Project ReCharge curriculum. Results show students content knowledge significantly increased with a medium effect size (Pretest: $M = 17.87$; $SD = 6.00$; Posttest: $M = 21.80$; $SD = 6.57$; $t = 9.25$; $p < 0.001$; $d = 0.63$) suggesting the methods used to teach the content led to an increase in energy, and energy efficiency knowledge, and rejecting the null hypothesis for year one.

Year two.

Twenty middle and high school classes totaling 1676 students were involved in the project in year two. The content test from year one was shortened from forty to thirty questions for the second year of implementation. Pretest data were collected throughout the month of August 2015, and posttest data were collected at the end of unit three, but no later than June 1, 2016. Missing or incomplete data were removed prior to analysis. Data from the content test were collected on 1338 of the students in a pretest/posttest administration. A power analysis was run on the data and resulted in a power of 1.00 for 1338 students with an effect size of 0.8. A paired samples *t*-test was applied to the data to determine if students content knowledge increased as a result of the Project ReCharge curriculum. The results show students content knowledge significantly increased with a large effect size (Pretest: $M = 9.24$; $SD = 4.39$; Posttest: $M = 16.63$; $SD = 5.31$; $t = 41.194$; $p < 0.001$; $d = 1.52$) suggesting the methods used to teach the content were sufficient for students to learn the content.

A paired samples *t*-test was applied to the high schools and middle schools separately. The high schools had a total of 565 students. Significant increases were found between the pretest and posttest (Pretest: $M = 11.03$, $SD = 4.53$, Posttest: $M = 16.45$, $SD = 5.39$ $t = 9.973$, $p < 0.001$, $d = 1.09$). The middle schools totaled 773 students and also made significant growth between the pretest and posttest with a large effect size (Pretest: $M = 7.93$, $SD = 7.38$, Posttest: $M = 16.76$, $SD = 5.25$ $t = 39.180$, $p < 0.001$, $d = 1.38$). The results of both tests provide evidence that the methods used in the Project ReCharge curriculum are beneficial to students in grades 7-12. As a result, the null hypothesis was rejected for year two implementation. Refer to Appendix D, Table 4 for year two content test analyses.

Year three.

Eleven middle and high school classes totaling 2320 students were involved in the project in the third and final year of the grant. Missing or incomplete data were removed prior to any analysis being conducted. Data from the content test were analyzed on 1055 of the students in a pretest/posttest administration. Pretest data were collected throughout the month of August 2016, and posttest data were collected at the end of unit three, but no later than June 1, 2017. A power analysis was run on the data and resulted in a power of 1.00 for 1055 students with an effect size of 0.8. A paired samples *t*-test was applied to the data to determine if students content knowledge increased as a result of the Project ReCharge curriculum. The results show students content knowledge significantly increased with a large effect size (Pretest: $M = 11.60$; $SD = 4.49$; Posttest: $M = 15.98$; $SD = 5.83$; $t = 27.302$; $p < 0.001$; $d = 0.086$) suggesting the methods used to teach the content were sufficient for students to learn the content.

A paired samples *t*-test was applied to the high school and middle school data separately. The high schools had a total of 392 students. Significant differences were found between the pretest and posttest (Pretest: $M = 12.13$, $SD = 5.10$, Posttest: $M = 15.96$, $SD = 5.70$ $t = 14.696$, $p < 0.001$, $d = 0.95$). The middle schools totaled 663 students and also made significant growth between the pretest and posttest with a large effect size (Pretest: $M = 11.28$, $SD = 4.07$, Posttest: $M = 15.99$, $SD = 5.91$ $t = 23.21$, $p < 0.001$, $d = 0.75$). The null hypothesis was rejected for year three. The results the year three content analyses can be found in Appendix D, Table 5.

All three years.

Data for all three years of the grant were combined to get an understanding of the project's effectiveness for the entire life of the grant. Pretest and posttest data were collected on 2616 middle and high school students over the three years. Scores for pretests and posttests were collected between April 2014 and June 1, 2017. Missing or incomplete data were removed from the data set prior to statistical analyses being completed. Student content data for all three years were analyzed using a two-tailed, paired samples *t*-test. The analysis was applied to all students in the life of the project, and then to the middle school students and high school students separately. A post hoc power analysis was conducting resulting in a power of 1.00 with an alpha of 0.05 and an effect size of 0.5 for the given sample size. Results of the two-tailed, paired samples *t*-test indicate increases in energy efficiency content knowledge for all students in all three years as well (Pretest: $M = 11.38$, $SD = 4.97$, Posttest: $M = 16.67$, $SD = 5.83$, $t = 45.05$, $p < 0.001$, $d = 0.98$). Data were collected on 1386 middle school students over the three years and analyzed using a two-tailed, paired samples *t*-test. Results indicate an increase in content knowledge from pretest to posttest with a large effect size (Pretest: $M = 9.82$, $SD = 3.94$, Posttest: $M = 16.37$, $SD = 5.61$, $t = 41.61$, $p < 0.001$, $d = 1.37$). High school students totaled 1230 students over the three years. Results indicate a significant increase in content knowledge from pretest to posttest (Pretest: $M = 13.14$, $SD = 5.40$, Posttest: M

= 17.00, $SD = 6.04$, $t = 23.19$, $p < 0.001$, $d = 0.68$). The null hypothesis can be rejected for all three years, and the alternative hypothesis accepted, suggesting students content knowledge was greater after they participated in Project ReCharge than before. Results of the content test for all three years can be found in Appendix D, Table 6.

Question Two

Question two addresses if changes in student attitudes towards STEM subjects and careers occurred as measured by the STEM Semantics Survey (Tyler-Wood et al., 2010). The null hypothesis assumes student attitudes from pretest to posttest would result in no changes.

Year one.

Students were administered the STEM Semantics Survey (Tyler-Wood et al., 2010) at the same time as the content pretest and posttest. Missing or incomplete data were removed from the data set prior to analysis. Data were only collected on high school students in year one. A total of 210 pairs of data were collected and a Wilcoxon Matched Pairs Signed Ranks analysis was applied to the data. A post hoc power analysis revealed a power of 0.99 with an alpha of 0.05 and an effect size of 0.5 for the analysis. Results indicate a significant increase in attitudes towards overall STEM subjects and careers with a small to medium effect size ($z = -2.314$, $p = 0.021$, $\eta^2 = 0.013$). The data were then disaggregated into each subject. Results suggest students' attitudes increased in science ($z = -3.555$, $p < 0.001$, $\eta^2 = 0.049$), engineering ($z = -2.363$, $p = 0.018$, $\eta^2 = 0.033$), and STEM careers ($z = -2.459$, $p = 0.014$, $\eta^2 = 0.021$) all with small effect sizes. Attitudes towards mathematics ($z = 0.525$, $p = 0.60$, $\eta^2 = 0.002$), and technology ($z = 0.964$, $p = 0.335$, $\eta^2 = 0.001$) showed no changes. Thus, the null hypothesis can be accepted for science, engineering, careers, and overall STEM interest, however the null hypothesis is accepted for math and technology subjects in year one. Results for year one STEM Semantics Survey data can be found in Appendix D, Table 7.

Year two.

Students took the STEM Semantics Survey (Tyler-Wood et al., 2010) at the same time as the content assessment. The pretest was given in August 2015 and the posttest was administered to students at the end of unit three, but no later than June 1, 2016. Missing or incomplete data were removed prior to analysis. Data were collected on total of 1125 middle and high school students. A Wilcoxon Matched Pairs, Signed Ranks analysis was applied to all students in year two. A post hoc power analysis was conducted and resulted in a power of 1.00 with an alpha of 0.05 and an effect size of 0.5. Results of the analysis indicate a significant increase in attitudes towards science ($z = 3.448$, $p < 0.001$, $\eta^2 = 0.007$), math ($z = 2.378$, $p = 0.017$, $\eta^2 = 0.006$), and overall STEM subjects and careers ($z = 2.382$, $p = 0.017$, $\eta^2 = 0.002$) all with a small effect size. No changes were found in engineering ($z = 0.958$, $p = 0.338$, $\eta^2 < 0.001$), technology ($z = 1.497$, $p = 0.134$, $\eta^2 = 0.001$), or careers alone ($z = 1.804$, $p = 0.071$, $\eta^2 = 0.002$). Thus, the null hypothesis can be rejected for science, math and overall STEM subjects and careers in year two. However, the null hypothesis is accepted for engineering, technology and careers in year two. Results of the STEM Semantics Survey for all students in year two can be found in Appendix D, Table 8.

The results for middle school and high school students were then analyzed separately. No differences were found for middle school students in any area: science ($N = 738$, $z = 1.645$, $p = 0.100$, $\eta^2 = 0.001$), math ($N = 731$, $z = 1.832$, $p = 0.067$, $\eta^2 = 0.006$), engineering (N = 727, z = 0.700, p = 0.484, $\eta^2 < 0.001$), technology (N = 732, z = 1.034, p = 0.301, $\eta^2 < 0.001$), careers (N = 724, z = 1.556, p = 0.120, $\eta^2 = 0.002$), or overall STEM (N = 738, z = 1.582, p = 0.114, $\eta^2 < 0.001$). Effect sizes were small to very small for all analyses suggesting results were not due to error. As a result, the null hypothesis is accepted for middle school students in year two. Results of the year two STEM Semantics Survey can be found in Appendix D, Table 9.

Results of the high school analyses show significant increases in science interests with a medium effect size (N = 386, z = 3.668, $p < 0.001$, $\eta^2 = 0.031$), and overall STEM interests with a small effect size (N = 386, z = 1.961, p = 0.050, $\eta^2 = 0.012$). No significant differences were found in math (N = 385, z = 1.524, p = 0.128, $\eta^2 = 0.006$), engineering (N = 384, z = 0.673, p = 0.501, $\eta^2 < 0.001$), technology (N = 383, z = 1.092, p = 0.275, $\eta^2 = 0.004$), or careers (N = 383, z = 0.876, p = 0.381, $\eta^2 = 0.001$). The null hypothesis is rejected for science and over STEM attitudes, but accepted for math, engineering, technology and careers for year two high school students. Results for the high school STEM Semantics Survey can be found in Appendix D, Table 10.

Year three.

Students took the STEM Semantics Survey (Tyler-Wood et al., 2010) at the same time as the content assessment. The pretest was given in August 2016 and the posttest was administered to students at the end of unit three, but no later than June 1, 2017. Missing or incomplete data were removed prior to analysis. Data were collected on total of 1028 middle and high school students. A Wilcoxon Matched Pairs, Signed Ranks analysis was applied to all students in year two. A post hoc power analysis was conducted and resulted in a power of 1.00 with an alpha of 0.05 and an effect size of 0.5. Results of the analyses report significant decreases in student interest towards science with a small effect size ($N = 1028$, $z = 2.229$, $p = 0.021$, $\eta^2 = 0.002$), and engineering interest with a small effect size ($N = 1013$, $z = 2.254$, $p = 0.024$, $\eta^2 = 0.004$), thus rejecting the null hypothesis and suggesting participation in the program leads to less interest in these areas. No significant changes were found for math, ($N = 1021$, $z = 0.786$, $p = 0.432$, $\eta^2 < 0.001$), technology ($N = 1013$, $z = 1.935$, $p = 0.053$, $\eta^2 = 0.005$), careers ($N = 1000$, $z = 1.053$, $p = 0.293$, $\eta^2 = 0.002$), or overall STEM interests ($N = 1028$, $z = 1.617$, $p = 0.106$, $\eta^2 = 0.001$), which all had small effect sizes, thus accepting the null hypothesis for these topics. Results for the year three results can be found in Appendix D, Table 11.

The results for middle school and high school students were then analyzed separately. Middle school students showed significant decreases in interest from pretest to posttest in science ($N = 715$, $z = 3.757$, $p < 0.001$, $\eta^2 = 0.015$), engineering ($N = 704$, $z = 3.117$, $p = 0.002$, $\eta^2 = 0.013$), technology ($N = 703$, $z = 3.178$, $p = 0.001$, $\eta^2 = 0.016$), and overall STEM ($N = 715$, $z = 2.648$, $p = 0.008$, $\eta^2 = 0.006$) all with small effect sizes. No significant changes in interests were found in the areas of math ($N = 710$, $z = 1.106$, $p = 0.269$, $\eta^2 = 0.001$) or careers ($N = 693$, $z = 1.226$, $p = 0.220$, $\eta^2 = 0.002$). The null hypothesis can be rejected for the subjects of science, engineering, technology and overall STEM suggesting student participation in the program decreased interest in these areas. However, the null hypothesis can be accepted for the areas of math and careers suggesting the program does not change student interests in these areas. Results for the middle school STEM analyses can be found in Appendix D, Table 12.

No differences were found for high school students in any area: science ($N = 313$, $z = 1.530$, $p = 0.126$, $\eta^2 = 0.015$), math ($N = 311$, $z = 0.267$, $p = 0.789$, $\eta^2 = 0.001$), engineering (N = 310, z = 0.749, p = 0.454, η^2 = 0.002), technology (N = 310, z = 1.343, p = 0.179, η^2 = 0.003), careers (N = 307, z = 0.000, p = 1.000, $\eta^2 < 0.001$), or overall STEM interests (N = 313, z = 1.028, p = 0.304, η^2 = 0.006). Effect sizes were small to very small for all analyses suggesting results were not due to error. As a result, the null hypothesis is accepted for high school students in year two. Results of the year three high school STEM Semantics Survey can be found in Appendix D, Table 13.

All three years.

Data for all three years were analyzed together to evaluate the overall effectiveness of Project ReCharge at increasing student interest in STEM subjects and careers. Pretest and posttest data were collected on 2363 middle and high school students over the three years. Scores for pretests and posttests were collected between April 2014 and June 1, 2017. Missing or incomplete data were removed from the data set prior to statistical analyses being completed. Student content data for all three years were analyzed using a Wilcoxon Matched Pairs, Signed Ranks test. The analysis was applied to all students in the life of the project, and then to the middle school students and high school students separately.

Results of the STEM Semantics Survey for all students in all three years suggest increases in science attitudes (N = 2362, z = 2.618, p = 0.030, η^2 = 0.002), and math attitudes (N = 2348, z = 2.280, p = 0.023, η^2 = 0.002) both with small effect sizes. No changes to attitudes towards engineering (N = 2335, z = 0.041, p = 0.967, $\eta^2 < 0.001$), technology (N = 2337, z = 0.310, p = 0.757, $\eta^2 < 0.001$), careers (N = 2316, z = 1.432, p = 0.152, $\eta^2 < 0.001$), or overall STEM interests (N = 2363, z = 1.398, p = 0.162, $\eta^2 < 0.001$), were found. Over the entire project span the null hypothesis can be rejected for science and math attitudes suggesting Project ReCharge can increase student interest in these areas. However, for engineering, technology, careers and overall STEM interests the null hypothesis is accepted suggesting the project has no effect on student attitudes in these areas. Results for the entire student population over the life of the grant can be found in Appendix D, Table 14.

Middle school students were then analyzed separately. Results from all three years show increased interest in math with a small effect size ($N = 1441$, $z = 2.145$ $p = 0.032$, $\eta^2 = 0.003$). No differences between pretests and posttest were found in any other area: science ($N = 1453$, $z = 0.930$, $p = 0.352$, $\eta^2 = 0.002$), engineering ($N = 1431$, $z = 1.263$, $p = 0.206$, $\eta^2 = 0.003$), technology ($N = 1435$, $z = 1.099$, $p = 0.272$, $\eta^2 = 0.003$), careers ($N = 1417$, $z = 0.529$, $p = 0.597$, $\eta^2 < 0.001$), or overall STEM interests ($N = 1453$, $z = 0.434$, $p = 0.665$, $\eta^2 = 0.001$) all with small effect sizes suggesting the results are not due to error. The null hypothesis is accepted for all subjects aside from math for middle school students when analyzing all data over the life of the project. Results for middle school students for all three years can be found in Appendix D, Table 15.

High school data were analyzed separately. Results of the analysis indicate increases in attitudes towards science ($N = 908$, $z = 4.900$, $p < 0.001$, $\eta^2 = 0.028$), technology ($N = 901$, $z = 2.050$, $p = 0.040$, $\eta^2 = 0.003$), and overall STEM ($N = 909$, $z = 3.006$, $p = 0.003$, $\eta^2 = 0.010$) all with small effect sizes. No differences were found for math interests ($N = 906$, $z = 0.908$, $p = 0.364$, $\eta^2 < 0.001$), engineering interests ($N = 903$, $z = 1.749$, $p = 0.080$, $\eta^2 = 0.004$), or STEM career interests ($N = 898$, $z = 1.701$, $p = 0.089$, $\eta^2 = 0.002$). The null hypothesis can be rejected for science, technology, and overall STEM interests for high school students, suggesting Project ReCharge can increase interests in these areas. Results for high school students for all three years can be found in Appendix D, Table 16.

Question Three

Question three seeks to understand if teachers' self-efficacy and teaching outcomes expectancy change between pretest, posttest, and post posttest. The STEBI-A was used to collect data for the three years of the grant.

Year one.

Five teachers participated in the pilot year of the project. A post hoc power analysis reveals a power of only 0.16 with an alpha of 0.05 and an effect size of 0.25. As a result of the low power, a Wilcoxon Matched Pairs, Signed Ranks Test was applied to the data collected by the STEBI-A. There were no missing data for this year of implementation. Teachers were administered the STEBI-A pretest in April 2014, and the posttest in May 2014. The Teaching Outcomes portion of the STEBI-A also showed no differences between the pretest and posttest differences (N = 5, z = 1.461; p = 0.42, η^2 = 0.020) with a sum of positive ranks of nine and a sum of negative ranks of only one. However, changes to science teacher efficacy and beliefs did change from pretest to posttest with a sum of negative ranks of 15 and a sum of positive ranks of zero (N = 5, z = 2.032; p = 0.042, η^2 = 1.00). These results indicate a decrease in personal science teaching efficacy beliefs as a result of participating in the program, thus rejecting the null hypothesis for science teacher efficacy and beliefs and suggesting the project decreases self-efficacy as a result of participating in the project and professional development. Results from year one teacher assessments can be found in Appendix D, Table 17.

Year two.

Twenty-one teachers participated in the second year of the project. A post-hoc power analysis was conducted resulting in a power of 0.675 for a repeated-measures AVONA. As a result, a Friedman Two-Way ANOVA by Ranks was applied to the three assessments given to the teachers. The pretest was given to teachers during the intensive professional development in July 2015. The posttest was administered to teachers in December 2015 and the post posttest was administered to teachers in May 2016. There were no missing data sets for teachers in the second year of the grant. Results of the Efficacy and Beliefs portion of the assessment show no differences between the three administrations of the assessment with a small effect size (N = 21, x^2 = 1.089; p = 0.580, η^2 = 0.022) nor did the results of the STEBI-A Teaching Outcomes (N = 21, x^2 = 5.158; p = 0.076 η^2 = 0.020). The null hypothesis can be accepted, suggesting participation in the project does not change teachers' science teaching efficacy and beliefs or science teaching outcomes. Due to the assessment being administered to the same group of participants, alpha slippage may have occurred. Results from year two teacher assessments can be found in Appendix D, Table 18.

Year three.

Thirty-four participating teachers were given both the pretest, posttest, and post posttest content test related to energy and energy efficiency for Project ReCharge at the beginning of the three-day professional development (July 2016), at the end of the first semester (December 2016) and again at the end of the second semester (May 2017). Complete data sets were collected for 19 teachers, meaning three teachers had missing data or incomplete data that were eliminated prior to analysis. A post-hoc power analysis was run on the data and resulted in a power of 0.62 for 19 teachers with an effect size of η^2 = 0.25 if a repeated measures ANOVA were to be applied to the data. As a result, a Friedman Two-Way ANOVA by Ranks was applied instead. No differences were found for either portion of the STEBI-A: Self-Efficacy and Beliefs (N = 19, x^2 = 3.226; p = 0.199, η^2 = 0.083) nor Teaching Outcomes: (N = 19, x^2 = 3.171; p = 0.205, η^2 = 0.085). However, both sections revealed medium effect sizes suggesting additional data collection needs to be done to determine if differences actually exist. Due to the assessment being administered to the same group of participants, alpha slippage may have occurred. The null hypothesis can be accepted, suggesting the project does not affect teacher self-efficacy in science or outcome expectancy in science teaching for year three teachers. Results of the year three teacher analyses can be found in Appendix D, Table 19.

All three years.

A comparison between years two and three using a one-way, repeated measures Analysis of Variance (ANOVA) was completed. Year one was not included in the analysis due to participants only taking two administrations of the assessment. Missing data or incomplete data for any of the three administrations in year two or three were eliminated prior to running the ANOVA for each test: content test and STEBI-A. Post hoc, multiple comparison Sidak tests were also completed to determine where differences exist in the data, if applicable. Due to the assessment being administered to the same group of participants, alpha slippage may have occurred.

Data from 38 year two and year three teacher participants were combined for analysis of the Efficacy and Beliefs portion of the STEBI-A (Enochs & Riggs,1990). A repeated measures ANOVA was applied to the data. No differences were found among the three administrations, (Λ = 0.939, F(2, 36) = 1.176, p = 0.320, η^2 = 0.061). Teachers did not show differences among the administrations of pretest and posttest (pretest M = 23.29, posttest M = 23.91, p = 0.559) or between posttest to post posttest (posttest M = 23.92, post posttest M = 23.08, p = 0.480). Nor did differences exist between the pretest and post posttest (pretest M = 23.29, post posttest M = 23.08, p = 0.986). An ANOVA was also applied to the Outcomes Expectancies portion of the STEBI-A. Results of the Repeated Measures ANOVA suggest no differences between any administration of the assessment (Λ = 0.901, F(2, 36) = 0.901, p = 0.152, η^2 = 0.099). No differences between the pretest and posttest exist (pretest M = 28.26, posttest M = 29.11, p = 0.654), nor were any differences found between the posttest and post posttest (posttest M = 29.11, post posttest M = 29.89, p = 0.705), or pretest and post posttest (pretest M = 28.26, post posttest M = 29.89, p = 0.144). As a result the null hypothesis is accepted suggesting participating in the project has no affect on teacher self-efficacy or teaching outcomes expectancies.

Question Four

Question four seeks to understand if changes to teacher content knowledge changed between pretest, posttest, and post posttest. The content test created for the students was used to collect data for teacher participants.

Year one.

Five teachers participated in the pilot year of the project, and data were collected on all participants; there was no missing data for teachers in year one. A post hoc power analysis reveals a power of only 0.16 with an alpha of 0.05 and an effect size of 0.25. As a result of the low power, a Wilcoxon Matched Pairs, Signed Ranks Test was applied to the data for the content test. Results of the content test analysis show no significant differences between pretest and posttest ($N = 5$, $z = 0.272$; $p = 0.785$, $\eta^2 = 0.067$), suggesting the teachers' content knowledge remained the same through the professional development and implementation of the curriculum, and accepting the null hypothesis. However, a medium effect size for the analysis suggests additional data needs to be collected and analyzed to determine the effects of the professional development and project on teachers' content knowledge. Results of year one teacher analyses can be found in Appendix D, Table 17.

Year two.

Twenty-one teachers participated in the second year of the project. Teachers were given the content pretest at the beginning of the summer professional development in July 2015, the posttest in December 2015, and the post posttest in May 2016. There were no missing teacher data in the second year of the grant. A post-hoc power analysis was conducted resulting in a power of 0.675 for a repeated-measures ANOVA. As a result, a Friedman Two-Way ANOVA by Ranks was applied to the three content assessments given to the teachers. Results of the content analysis show no significant differences between the pretest, posttest, and post posttest ($N = 21$, $x^2 = 5.158$; $p = 0.076$, $\eta^2 = 0.292$), thus accepting the null hypothesis. However, the resulting effect size was large suggesting additional research needs to be done to determine if differences actually exist as a result of participation in the program and professional development. Due to the assessment being administered to the same group of participants, alpha slippage may have occurred. Results of year two teacher analyses can be found in Appendix D, Table 18.

Year three.

Thirty-four participating teachers were given the pretest, posttest, and post posttest content test related to energy and energy efficiency for Project ReCharge at the beginning of the three-day professional development (July 2016), at the end of the first semester (December 2016) and again at the end of the second semester (May 2017). Complete data sets were collected on 23 teachers. Teachers with missing or incomplete data were removed prior to analysis. A post-hoc power analysis was run on the data and resulted in a power of 0.72 for 23 teachers with an effect size of $\eta^2 = 0.25$ if a repeated measures ANOVA were to be applied to the data. As a result, a Friedman Two-Way ANOVA by Ranks was applied to the data resulting in significant increases in content knowledge over the course of the year with a very large effect size ($N = 22$, $x^2 = 5.158$; $p = 0.076$, $\eta^2 = 0.319$). Results of year three teacher analyses can be found in Appendix D, Table 19.

A Wilcoxon Matched Pairs, Signed Ranks Test was then applied to pairs of data to determine where differences exist. Significant increases were found between the pretest and posttest with a very large effect size ($N = 23$, $z = 3.384$, $p = 0.001$, $\eta^2 = 0.350$), and between the pretest and post posttest with a very large effect size ($N = 23$, $z = 3.309$, $p = 0.001$, $\eta^2 = 0.387$). However, no differences were found between the posttest and post posttest ($N = 23$, $z = 0.531$, $p = 0.596$, $\eta^2 = 0.008$). Due to the assessment being administered to the same group of participants, alpha slippage may have occurred. The results suggest teachers' content knowledge increased between the pretest and posttest and was maintained throughout the year of implementation as a result of participating in the professional development and implementing the project in their classrooms. Therefore, the null hypothesis can be rejected for year three of implementation.

All three years.

A comparison between years two and three using a one-way, repeated measures Analysis of Variance (ANOVA) was completed. Year one was not included in the analysis due to participants only taking two administrations of the assessment. Missing data or incomplete data for any of the three administrations in year two or three were eliminated prior to running the ANOVA for each test: content test or STEBI-A. Post hoc and multiple comparison tests were also completed to determine where differences exist in the data, if applicable.

Data for thirty-six teachers were run for the content test analysis. Results of the repeated measures ANOVA show differences between all three administrations of the content test for teachers ($\Lambda = 0.596$, $F(2, 34) = 11.521$, $p < 0.001$, $\eta^2 = 0.276$). A Sidak comparison for multiple comparisons was applied to the data to adjust for alpha slippage. Differences exist between the pretest and posttest (Pretest $M = 23.33$, posttest $M = 25.53$, $p = 0.002$), the pretest to post posttest (pretest $M = 23.33$, post posttest $M = 26.06$, $p < 0.001$), however no differences were found between the posttest and post posttest (posttest $M = 25.53$, post posttest $M = 26.06$, $p = 0.706$) showing teachers knowledge increased from pretest to posttest, and then maintained the level of content knowledge from posttest to post posttest. Due to the assessment being administered to the same group of participants, alpha slippage may have occurred. A post hoc power analysis was applied to the data resulting in an observed power of 0.997 for the analysis.

Chapter Five: Discussion

Project ReCharge was designed with the goals of increasing student knowledge in the area of energy and energy efficiency, increasing student attitudes towards STEM subjects and careers, increasing teacher self-efficacy in teaching science, and increasing teacher content knowledge. Over three years, eleven schools participated in the project, as well as 47 teachers, and 4,123 students engaged in the curriculum. The five-unit curriculum provided students with integrated STEM lessons utilizing more structured inquiry techniques at the beginning of the curriculum and more open-ended inquiries by the end of the curriculum. Teachers were provided with intensive professional development prior to their implementation of the program in their classrooms, as well as monthly professional development for the remainder of their year of participation. Students in each year of implementation received two assessments in a pretest/posttest administration to determine the effectiveness of the program: a content test and the STEM Semantics Survey (Tyler-Wood et al., 2010). Teachers were given multiple assessments as well, including the content test and the STEBI-A.

Findings from the statistical analyses collected over the three-year period provide evidence that aspects of the Project ReCharge program were effective in relation to the research questions. This section provides a discussion of the statistical findings in relation to each research question. Current literature is used to contextualize and interpret the results, and further support conclusions drawn from the statistical analyses. As a regular function of the grant, formative assessments were included as a portion of the project evaluation. Focus groups occurred at the end of the second and third year of implementation of the project and were grouped by middle school and high school participants. Additionally, survey data about the professional development were also collected from the teacher participants yearly. These sources of data provide insight into the statistical results and are used to help support conclusions made about the statistical analyses.

Increases in Student Content Knowledge

Research question one relates to the change in student content knowledge as a result of participation in the project. In all three years of the grant student content knowledge significantly increased in the area of energy and energy efficiency ($p < 0.001$). Medium to large effect sizes ($d = 0.626$-1.52) were found for all students in each year of the grant as well as the disaggregated populations of middle school students and high school students. These results suggest the methods of inquiry and lessons used in the project provide an adequate format to teach middle and high school students the basic content of energy and energy efficiency.

These results are consistent with research supporting the use of inquiry teaching techniques and academic achievement in the sciences. In a five-year analysis conducted by Marshall and Alston (2014), teachers who received professional development on inquiry instruction and enacted inquiry teaching techniques in the classroom had students who consistently scored higher on science assessments, such as the Measures of Academic Progress than did their peers who did not receive inquiry formats of instruction. This held true for students of minority populations as well including female, African-American, and Hispanic populations which is pertinent to this study as many of the participants came from low SES schools and comprised a diverse population. The difference in scores for the experimental group and the control group showed significant difference at the end of each academic year ($p < 0.001$) showing the inquiry techniques increased academic achievement more than traditional methods. Although the current study did not use a control group, students did receive instruction in inquiry formats, progressing from structured to open, which was presented by teachers who underwent intensive professional development that included inquiry instruction techniques.

Although student content knowledge increased significantly in all years of implementation, an interesting note is the value to which they all increased in the posttest. The content test created for year one had forty questions, however after the first year, participating teachers asked that the test be shortened due to the time required to take the assessment. Thirty questions were chosen and checked for content validity by professionals in the field. In the second and third year of implementation students' maximum score hovered around sixteen for all groups: all students, middle school students, and high school students (posttest M = 15.96-16.76). With the test being edited, it still represented content from the original unit progression of lessons in the units of study for the project. However, in order to keep the instrument valid, under the direction of the statistical constant, the instrument was not altered beyond the original edit so that measurements could be compared from year to year. With that said, the assessment did not adapt to other smaller changes in the program.

The focus group transcript from year two middle school teachers also suggest a mismatch between the content assessment and the curriculum. One teacher stated "the test is very vocabulary heavy, but the content is not really taught in the curriculum. Yeah, it's mentioned, but not necessarily *taught*". The focus on vocabulary in the content test could also limit the interpretation of the content test results in relation to the intended presentation format of the curriculum. Professional development surrounded instruction through inquiry techniques, with the intent of using those techniques to provide students with a deeper understanding of the content. As mentioned above, studies commonly find increases in student content knowledge when taught through inquiry formats. However, other studies have suggested utilizing direct instruction techniques focused on science vocabulary can increase student achievement as well (McAdams, 2012). The study suggests disadvantaged populations benefit from direct instruction in vocabulary when compared to their peers who did not receive the direct instruction ($p = 0.03$). Suggesting students are able to learn those vocabulary words and use them for the assessment.

The NGSS supports contextualizing vocabulary instruction and is a secondary objective to understanding the phenomenon being explored utilizing their current vocabulary. After connections have been made between the language students already have and the phenomenon, teachers can then tailor instruction to present academic vocabulary in a more relevant format for students (NGSS Lead States, 2013). As a result, the content test may have been too traditional to assess the three dimensional instruction presented in the curriculum.

In the third year of implementation, teachers became very concerned about the time required to implement the program, and many reverted back to a more direct instruction format for presenting the information to the students. Several middle school teachers in the focus group said they actually did more direct instruction with the program than they would otherwise. One teacher specifically said, “I’m finding we need to do a lot of front-loading, especially with the vocabulary…and I know you’re not supposed to, but our students need it and there’s no way around it.” One teacher even requested “some reading to do before students do the lab, so they know the content,” illustrating a lack of teacher knowledge and trust of inquiry teaching.

Although increases in content knowledge were found with every implementation of the curriculum, it is difficult to say these changes were strictly due to the program. The change from inquiry instruction to more direct instruction techniques is not measured by the content assessment, however when evaluating the program as a whole, the content assessment is not enough to determine if the program, as intended, increased content knowledge.

This traditional format to determine proficiency with content knowledge remains a problem when assessing an inquiry program aligned to the three-dimensions in the NGSS (NGSS Lead States, 2013). The National Research Council (2014) suggests providing performance tasks and scoring rubrics to assess levels of mastery rather than the traditional, multiple-choice assessments that only measure one dimension, the DCI.

Student Interest in STEM Subjects and Careers

The second research question relates to if student interest in STEM subjects and careers changed as a result of participating in the program. Student groups from each year showed increased interest in different areas. However, there were some similarities between groups from year to year. High school students tended to show the most increases in attitudes in the areas of science and overall STEM. This was true for year one, year two, and all three years combined. Additional increases at the high school level were seen in engineering and careers in year one, and technology across all three years. The only area that did not show significant changes at the high school level for any year was mathematics. This could be the result of the structure of the STEM lessons focusing on the science and engineering components and using math more traditionally as a tool. Another rational as to the lack of results in math could be due to the math being so embedded in the instruction that students may not have recognized it as being math instruction. Changes to high school interests in technology did not exist for yearly data. Even with the use of the LoadIQ hardware to monitor loads in real-time at the school site, changes were not seen until analyzed across the life of the grant. One rationale for the lack of change in interests in technology when such a new piece of technology is introduced and used at the school site could be the generational comfort with technology and its uses in daily life. As with math, the technology was being used as a tool much the same as it has always been for this generation of students.

Middle school students did not show the same increases, and in fact, only show increased interest over all three years in the area of math ($p = 0.023$). Middle school students in year two showed no change in attitudes, and only increases were revealed in the area of math over all three years of implementation ($p = 0.032$). In fact, middle school interests decreased in year three in the areas of science, engineering, technology, and overall STEM (see Appendix D, Table 12).

The focus groups help to provide a rationale as to why increases to interests were more prevalent in the high school classes than in the middle school classes. The middle schools in the local district are transitioning from teaching isolated science classes to an integrated approach, where the NGSS are no longer separated by DCI for a class (Biology, Physics, etc.) but are separated to include performance expectations for all four DCIs in each grade level. As a result, participating middle school teachers were not able to teach the curriculum all at once, due to the pacing guide provided by the district. The high school curriculum is still subject specific, allowing teachers in the physics and environmental classes to spend more time getting into the curriculum without having to address other DCIs. One high school reported using the whole year to implement the curriculum, and was able to teach all the required lessons as well as the optional and extra lessons provided by the project. This ability to teach Project ReCharge as an isolated class allowed more time to be spent getting into the projects and hands-on activities.

Whereas high school teachers were given more control over their courses and the content, middle school teachers in the third year of implementation reported frustration with the strict guidelines from the district and their inability to integrate the lessons with others in their school (such as the math teacher) in order to complete the project. Additionally, since teachers were implementing multiple DCIs into their classes, they reported not having enough time to really implement the curriculum as intended. One teacher reported “all the lessons are aligned to the NGSS, however I have 80 DCIs to get through now, and the curriculum only covers about five, but it takes an entire semester to complete. And I just don’t have the time.” Another teacher agreed the amount of time needed to teach the curriculum was much more than expected and couldn’t reasonably be done as intended, following with her concern about her students standardized testing scores for the year, “Next year, science tests now count as part of our evaluation, so you’re going to get a lot of push back because we aren’t covering all our standards. It’s taken me three terms to teach…I like doing it, but I’m scared to see my scores this year.”

These time restrictions reported by middle school teachers in year three created changes to the curriculum that could be the cause of decreasing interests. As well as the front loading of the content discussed earlier, teachers reported changing the lessons to make them fit within a class period, “Lesson were a lot longer than what is written in the guides, so in actuality, we have 50-minute class periods, and to complete the whole 5E lesson just isn’t possible, so we needed to do a lot of frontloading to make the labs go quicker.” Many teachers reported switching to doing more teacher talk than what was written into the curriculum. One teacher stated conducting the lessons as written, in a 5E discovery format wasn’t working for his students, “If you didn’t give them direction and information up front then kids were all over the place”. Many teachers did not like the idea of students being at different places in the activities because it meant different finishing points, which was hard to organize in a fifty-minute time frame.

Not many teachers in middle school were able to conduct lessons in the inquiry format prescribed by the program and presented in the professional development, and instead opted to front load content in a teacher directed format, sometimes even skipping the hands-on activities altogether. The amount of teacher talk conducted could be the reason student interests decreased in year three. Literature suggests students who have a personal connection and buy-in hold and maintain greater interests in STEM fields (Christensen, Knezek, & Tyler-Wood, 2015). The authors of the study report middle and high school students engaged in hands-on STEM activities at home, in school, and in after school programs are more likely to maintain positive STEM dispositions which can lead to greater interests towards careers in these fields. These active learning environments were found to be especially meaningful when engaging students in real-world problems, and was believed to be the reason students interest in STEM increased (Christensen et al., 2015). Changing the inquiry format to a teacher-directed format eliminates the student buy-in and engagement. Especially when teachers report normally doing more inquiry based lessons, and then shifted to direct instruction only when teaching the Project ReCharge curriculum, students could feel more negative, noting they don't get to actively participate but just listen to learn.

One possibility for this shift in instruction could be due to the inexperience of the professional development team in the second and third years of implementation. Professional development in the first year of implementation was organized and conducted by trained instructors with a background in teacher education. That shifted in the second year allowing more of the instruction to be conducted by Envirolution in preparation for the program to be carried out past the end of the current grant. By the third year most of the professional development responsibility was placed with Envirolution. Although the intent was to create adequate teacher learning opportunities, the lack of knowledge about professional development and teacher training does not allow for changes to practice in the classroom.

One teacher reported that when she allowed the students to actually explore the phenomenon "they actually did enjoy doing the activities and getting into the stuff", but it was really hard for her to relinquish control and allow students more time than she traditionally would. Another teacher agreed that when the students got into the hands-on activities they were engaged and excited to learn, "the students loved the activities and would say 'wow, you're teaching me real world stuff!' and I had to get over that [*testing and standards requirements*] and just let them go, they're learning, they're having a great time doing it, and they're super excited."

The format of instruction and pressures placed upon middle schools suggest a possible limitation when interpreting the STEM Semantics Survey data (Tyler-Wood et al., 2010). Studies suggest hands-on inquiry approaches to STEM education have been found in various studies to increase student interest in STEM subjects and careers, especially at the middle school level (Christensen et al., 2015; Hayden, Ouyang, Scinski, Olszewski & Bielefeldt, 2011). High school teachers tended to teach the curriculum from beginning to end as intended, whereas middle school teachers described breaking up the lessons and units to fit within the district pacing guide. These different implementation structures could have an effect on student interests in STEM subjects and careers. The integrated model required for middle schools in the local district was seen as a barrier to adequately implement the program, which might be better suited to a stand-alone course, more like the high school setting.

Professional Development and Teacher Self-Efficacy

Question three refers to changes in teachers' self-efficacy as a result of participating in the professional development and administering the project curriculum in their classrooms. No changes were found in the teaching outcomes portion of the STEBI-A for any year of implementation. Suggesting teachers' expectancies for their students' abilities to learn science didn't change. Although teachers' outcome expectancies did increase, it was not enough to show differences beyond error. The average scores in years one, two, and three were above the median of scores obtainable in the outcomes expectancies portion of the STEBI-A (see Appendix D, Tables 17, 18, and 19), which ranges from twelve to sixty, suggesting teachers started with high beliefs about their students' abilities to learn the science which was maintained throughout the implementation of the curriculum over the course of the year of participation. This is comparable to other studies that also found, teachers hold high beliefs about their students' abilities which are maintained (Lakshmanan, 2011).

Changes to teachers' self-efficacy remained constant as well in years two and three. With a median of 26 on the teachers' self-efficacy portion of the STEBI-A teachers from both years held slightly below average self-efficacy views. Average scores hovered around 21 for year two and 23 for year three, and did not show any increases or decreases throughout the year of participation. As reported by Lakshmanan (2011), many studies find increases in teachers' self-efficacy, but not necessarily in science teaching outcomes expectancy scores. Or conversely, many find decreases in one area as the other area increases (Shahid & Thompson, 2001).

Additional studies have found teachers scoring above 50 on this portion of the assessment were less likely to make any growth as were their peers who scored below 50 in the pretest. One rationale for this is the high level of self-efficacy teachers already hold when they reflect pretest scores above 50 on the assessment that ranges from thirteen to 63 (Roberts, Hensen, Thar, & Moreno, 2000). Additionally, it has been suggested that self-efficacy remains fairly constant and unchangeable once established (Bandura, 1997). Teachers who have been teaching for greater than ten years fit into this category (Herrington, Yeziershi & Bancroft, 2016). Additional data on years of experience would be beneficial to determine if the teacher participants fall into the same situation. The teachers in this research felt comfortable with the three-dimensional framework presented in the NGSS however, their comments in the focus groups show a limited ability to implement it, suggesting they knew how to teach and were comfortable with how they have always taught.

In the current study growth was not found in either area and, in fact, year one participants showed decreased self-efficacy scores from pretest to posttest with decreases from 23.6 to 19. These results show teachers started with beliefs slightly below the median to begin with, and ended with even poorer self-efficacy beliefs. The focus on the NGSS (NGSS Lead States, 2013) and inquiry techniques was reported to be slightly monotonous according to participants in year one, and based on the anonymous survey data collected about the professional development. Several participants thought too much instruction on the inquiry processes took place during the professional development, and another thought too much time was spent on the NGSS because "it seemed like everyone already know about how to implement the NGSS, so we didn't need as much instruction in that area *[compared to how much was given]*." These ideas were exhibited by many participants in the first year and suggest a possible over confidence in their abilities to implement the three dimensions of the NGSS with the prescribed inquiry practices. As a result, teachers may have gotten back to their classrooms and tried to implement the curriculum as intended, but found they were not as confident with the practices of inquiry as they though leading to a decrease in self-efficacy posttest scores.

The amount of changes middle school teachers reported applying to the curriculum, from more inquiry to more didactic, could also reflect a lack of results in these areas. Although inquiry was stressed and modeled in the professional development, teachers were limited to a given time frame for each class and for the semester. The integrated approach for middle school science classes seemed to create a lot of stress for participating teachers which caused them to revert back to more teacher directed approaches. One year two teacher reported the need to "make handouts that provided step-by-step directions and worksheets" just so the students could "get through a lesson". This lack of change to practice could be the reason no changes were found in the self-efficacy portion of the STEBI-A, as well as the decrease in STEM interest scores found in year three middle school results. The lack of change to practices suggests professional development did not alter their understanding of inquiry enough to make systematic changes to instruction, but instead forced them to get through the content in order to take the posttest required for the grant.

Increases to Teacher Content Knowledge

Research question four refers to changes to teacher content knowledge that may have occurred as a result of participating in the program. Analyses of year one and year two content test data for teacher participants show no changes between pretest and posttest or post posttest (for year two). This suggests teachers' content knowledge remained the same. Most teachers in years one and two scored high on the pretest suggesting they already had a strong fund of knowledge in the area of energy and energy efficiency. Many of the teachers in these two years taught the content in the aligned performance expectations already, and the introduction of the Project ReCharge curriculum was just a new way to teach the content.

However, year three teachers did show significant increases from the pretest to the posttest and pretest to post posttest suggesting teachers' content knowledge increased as a result of participating in the professional development and implementing the curriculum. Changes may have occurred in year three where they didn't occur in years one and two because of the implementation of an integrated middle school approach, rather than the stand-alone subjects in the previous years. This integrated approach allowed teachers from a greater variety of science backgrounds as well as math instructors to join in the project. These participants may not have started with as strong of a fund of knowledge that year one and year two did due to the populations that volunteered each year. Year one and year two teachers were all from the focused science areas aligned to the Project ReCharge curriculum, however year three teachers came from more diverse content areas some which were focused on physics and others that were math related. Although the teachers in the third year did not start with the same fund of knowledge surrounding energy, increases to content knowledge were made by the posttest which was maintained throughout the remainder of the year to the post posttest. In the end year three teacher participants were able to answer most of the questions on the content test correctly and held similar posttest scores to those teachers in years one and two.

Interestingly, although significant increases were only found in year three, effect sizes increased from very small in year one to medium in year two and large in year three. This could suggest that changes to professional development from year to year became more focused on teacher content knowledge needed to implement the curriculum. It could also suggest the pool of teacher participants from year to year came from more varied content backgrounds. Additional data would need to be collected to determine if differences actually exist.

Similar results to those found in the year three data have been reported by other studies (Seraphin, Philipoff, Parisky, Degnan & Warren, 2011). Results from a study by Seraphin et al. suggest teachers' science content knowledge in the area of energy increased with professional development focusing on inquiry practices. The study also reports that although, content knowledge increases additional professional development is needed to increase confidence in teaching energy topics through inquiry methods. Similar to the results found in the current research, professional development led to an increase in content knowledge but did not create change in self-efficacy or lead to use of more inquiry based formats of instruction.

Limitations of the Study

There are many limitations when interpreting the data for the current research. One major limitation comes from the variety of structures and strategies participating teachers used to implement the required lessons from the curriculum. High school teachers tended to teach the curriculum all at once while middle school teachers would implement it where they could within their school year. Some teachers taught the curriculum at the beginning of the school year and others waited until the last quarter, after standardized testing. Many teachers reporting adopting a more didactic approach to teaching the lessons, instead of the inquiry formats presented in the professional development and written into the lessons. Due to the variety of formats and timelines for implementing the curriculum, results in student STEM interest scores and content scores could be due to other factors not controlled for in this research.

Changes in the program also occurred from year to year. Professional development was tweaked based on information from participants in the prior year of implementation, the time allotted to the intensive summer professional development changed from year to year, and the content covered in each professional development session changed based on feedback from prior participants. Additionally, changes in professional development instructors changed from year to year based on availability, thus changing some of the structures in the professional development.

Results of the content test suggest an additional limitation. Although it was checked for content validity, the possibility exists that it did not accurately measure what was directly being taught in the curriculum, therefore not matching the constructs outlined in the program. As a result, this suggests a limitation in the use of the instrument to accurately assess changes to content knowledge. Questions about validity of the content assessment need to be addressed in order to adequately assess increases to content knowledge.

Data from returning teachers (those who participated for more than one year), and students who had gone through the curriculum in a previous grade were not accounted for. These participants were treated like new participants, although their scores reflect additional knowledge from participating in multiple years of the project. Additional data would need to be collected to determine what changes exist if someone participated multiple years in the project.

Implications of the Study

Based on the literature, data collection, and interpretation of the results for this study several implications could be made. A strong professional development plan, aligned closely to current literature sets the stage changes to teacher practices. Changes in teacher practices towards more inquiry approaches can develop more interest in STEM subjects and careers. Without a strong professional development plan and implementation, changes to science teacher self-efficacy and science teaching outcomes expectancies are unlikely to change. Supporting teachers' implementation of inquiry approaches instead of more teacher directed, didactic approaches can lead to increased interest in STEM. A common trend across districts in professional development is the train the trainer model. However, this model doesn't work when the individuals being trained lack an understanding in the shifts towards three-dimensional learning. This lack of understanding leads those individuals to inadvertently present one-dimensional learning opportunities to those taking the professional development, thus limiting the ability of participants to really plan and implement three-dimensional instruction. Those implementing professional need a strong understanding of the needs and knowledge base of the individuals taking the professional development, as well as a deep understanding of the theoretical and empirical research surrounding what they are teaching.

The NGSS require equal integration of each of the three dimensions in science and engineering. Traditional formats of instruction only focus on one dimension: the disciplinary core idea. Additionally, assessments still in use today to determine a student's proficiency in science content areas tend to only reflect the disciplinary core idea as well. As a result of the top down structure for what student should know based on how they are assessed, there is very little pressure on teachers to shift instruction from one-dimensional to three dimensional. Administrators and instructional leaders are more concerned with achievement scores than with the method of instruction. However, as the results in the current research have shown, students who are provided with three-dimensional learning experiences show the same academic achievement as those who are taught through one dimensional, didactic teaching methods. However, students who experience the more inquiry based approaches also show increased attitudes in STEM subjects and careers. With research suggesting positive attitudes are key to increasing the number of students who pursue courses and careers in STEM, it becomes imperative to focus instruction on the implementation of all three-dimensions in the NGSS.

However, with the perception of academic achievement being only content knowledge measured by traditional assessments, there is no reason for teachers to shift instruction away from a focus on teaching content. Assessments designed to assess all three dimensions would force teachers to shift instruction to incorporate not only the disciplinary core idea into instruction but also equally incorporate crosscutting concepts and science and engineering practices as well. Until that expectation is put in place across states, districts, and schools a focus on content alone with matching instructional methods remains acceptable.

Students are more engaged while getting to construct meaning of the natural world, or design a solution to a problem. When these inquiry approaches are combined with real-world applications student interest is piqued, creating a desire to learn more. Implementing this curriculum in a three-dimensional format allows students to make connections and develop solutions to real world problems. In turn, this drives to motivation to continue learning about the STEM challenges faced by society.

The literature suggests a lack in professionals trained in the STEM areas of energy and green energy, including renewable energy sources (BLS, 2016). Project ReCharge serves to introduce and ignite passion in middle and high school students to pursue STEM courses and degrees in these fields, and allow the United States to compete in the global marketplace (Buckley, 2009). Project ReCharge has been shown to increase attitudes in several STEM areas, especially at the high school level. Increasing attitudes can lead to higher academic achievement in STEM areas, as well as prompt students to continue taking courses in STEM (Newell et al, 2015; Ozel et al., 2006). Providing research based, STEM programs such as Project ReCharge in middle and high school is the first step to ensuring students have access to real-world programs that develop problem-solving skills. Additionally, when students are presented with the opportunity to utilize technology that they can manipulate and collect data based on variables they have chosen, they become invested in the data. Students in the current project were able to make proposals to their school site based on data collected in real time. Several proposals were implemented, and students can now collect data and make comparisons about the energy consumption prior to their proposals being implemented and after. When teachers allowed the students to be creators of knowledge and apply their knowledge in meaningful ways, they did and they can see the impacts their choices have made on their school site. Combining an integrated STEM program with the three-dimensions outlined in the NGSS allows students to experience the phenomenon, and begin to develop the STEM literacy needed to prepare them for careers in STEM, and make informed decisions about the world around them (Crawford, 2000).

Conclusion

The purpose of this research project was to determine the effectiveness of Project ReCharge based on quantitative data collected for four questions. These including changes to student content knowledge, changes to student attitudes towards STEM subjects and careers, changes to teacher self-efficacy and beliefs and teaching outcomes expectancies, and lastly changes to teacher content knowledge. Several components of the project were successful. Over the life of the grant, and for all student groups analyzed, the implementation of the Project ReCharge curriculum led to increased content knowledge in the area of energy and energy efficiency. Increases in content knowledge occurred across grade levels, and occurred with both inquiry instruction and more teacher-directed instruction. So, the project can be considered effective at increasing student content knowledge in the areas of energy and energy efficiency.

Changes to interest in various STEM subjects showed increases, but were not consistent across years or grade bands. High school students tended to hold increased attitudes towards a variety of STEM subjects more often than the middle school groups did. This could be the result of district mandates placed upon the middle school teachers beginning in the second year and being fully in place the third year of implementation, leading to greater stress to complete the requirements for the program and from the district. These top-down mandates created a time-crunch forcing a more direct instruction approach to the prescribed inquiry-based lessons written into the curriculum. High schools did not experience the same time crunch and were able to implement the curriculum more as it was intended, allowing for the inquiry to be the focus, which could be why interests in STEM increased more often and in more areas. This suggests the program could more successfully be implemented in the high school grade bands as a stand-alone course or in a course that has a single focus rather than using an integrated topic model, such as was found in the middle schools.

The professional development outlined in the program was aligned to current literature, however it did not fully implement all the attributes outlined in the literature, including reflective practices. More effective professional development utilizing more focused techniques matching current literature may lead to increased self-efficacy and science teaching outcomes for participating teachers. Although teachers already held high science teaching outcomes expectancies for their students and maintained those expectations, increasing the effectiveness of the professional development and aligning it with district initiatives might lower the stress placed on teachers who want to implement the program. Specifically, in the integrated middle school grades professional development may could create more confidence to implement and integrate the program into required pacing guides. This reduced stress could allow for teachers take more risks in implementing inquiry practices, which may result in higher students' attitudes in STEM subjects and careers.

When considering the effectiveness of Project ReCharge at increasing science teacher self-efficacy and teaching outcomes expectations, the project did not meet the expectation of increasing beliefs in these areas. Teacher content knowledge could also affect teachers' self-efficacy. Increases to teacher content knowledge could allow for teachers to focus on implementing the curriculum, and aligning inquiry practices rather than learning the content that they are teaching. Additional changes and research to the professional development are needed to ensure it is meaningful for teacher participants. Stronger professional development would allow for the increased teacher self-efficacy that has been found to promote greater content knowledge, and attitudes and interests in STEM subjects and careers which is a major goal of Project ReCharge.

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Appendix A

Curriculum Map

Unit One: Energy Basics	Unit Two: Thermal Systems	Unit Three: Electrical Systems	Unit Four: LoadIQ	Unit Five: Energy Saving Projects
1. Simple Circuits (r) 2. Series and Parallel Circuits (o) 3. Conductivity (o) 4. Humdinger Challenge (o) 5. Electrical Generation (r) 6. Energy Bike (o) 7. Solar Energy (r) 8. Wind Energy (r)	1. Three Spheres Sustainability (r) 2. Water Heating (o) 3. Building Envelope (r) 4. Cooling (r) 5. Heating (o)	1. Lighting (r) 2. Appliances (r) 3. Analyzing Home Energy Bills (r)	1. Exploring Outliers and Correlations (r) 2. Energy Trends (r) 3. Classroom Lighting Analysis (r) 4. Classroom Appliance Analysis (r) 5. School HVAC Appliance Analysis (r)	1. Energy Reduction Plan (r)

Appendix B

School and Student Demographics

Table 1

School Demographics

School	1M	1H	2H	2M	2M	2H	2H	3M	3M	3H	3M
Total Pop.	682	2,075	1,991	1,056	592	198	1,686	662	740	1,693	589
FRL	47.51	29.69	49.07	29.17	81.59	14.65	48.1	72.96	41.89	22.27	37.35
ELL	18.48	4.92	8.29	4.73	27.03	8.59	16.49	25.83	4.73	1.65	2.04
IEP	15.1	12.58	15.62	10.13	17.4	12.63	11.03	17.98	14.86	11.46	15.45
Female	46.77	48.18	46.41	50.38	44.26	10.61	48.28	45.77	47.57	47.73	47.54
Male	53.23	51.81	53.59	49.62	55.74	89.39	51.72	54.23	52.43	52.27	52.46
2 or more	5.28	5.4	5.32	7.76	5.41	6.57	4.03	2.72	8.11	6.02	8.15
Pacific Islander	-	1.35	1.1	1.14	-	-	0.71	-	-	-	-
White	34.31	48.92	45.71	55.11	21.28	57.07	26.33	17.52	62.57	68.69	64.52
Black	3.37	3.04	2.56	1.52	2.87	-	2.31	2.72	1.62	-	-
Hispanic	48.97	32.63	41.19	26.7	65.03	33.8	56.82	71.45	23.92	19.02	20.54
Asian	3.81	6.7	2.46	5.3	3.38	-	8.42	2.42	1.76	1.89	-
Am. Indian / Native Alaskan	-	1.98	1.66	2.56	-	-	1.36	-	-	3.31	5.26

Table 2

Student Demographics

		Gender			Grade							
	Total	Male	Female	Other	6	7	8	9	10	11	12	Other
Year 1	501	166	158	177	-	-	60	3	176	74	10	177
Year 2	1222	647	555	20	-	448	387	71	52	183	64	12
Year 3	2395	1285	1096	14	218	716	925	187	256	56	21	11

Table 1

Student Selected Race

	Am. Ind.	Asian	Black	Hispanic	Pac. Island	White	Other	No Id.
Year 1	1	23	22	115	1	211	9	119
Year 2	18	61	27	409	-	628	33	41
Year 3	41	101	63	895	-	921	289	83

Appendix C

Project Timeline

	2014	2015	2016	2017
January		Units One through Three finalized and trial run of units one through three		
February				
March				
April		Year One Intensive professional development and project implementation. Teacher and student assessments collected and analyzed for yearly reporting.		
May			Year two teacher post posttests and student assessments collected and analyzed for yearly reporting	Year three teacher post posttests and student assessments collected and analyzed for yearly reporting
June		Recruitment for year two teachers	Recruitment for year three teachers	
July		Year two intensive professional development	Year three intensive professional development	
August	Funding Approved, initial meeting between Envirolution and UNR	Student pretests administered, and teachers begin implementation of curriculum	Student pretests administered, and teachers begin implementation of curriculum	
September				
October	Project ReCharge Team meeting			
November	Creation of content test and recruitment of year one teacher participants			
December		Teacher posttests administered via SurveyMonkey.com	Teacher posttests administered via SurveyMonkey.com	

Appendix D

Results Tables

Table 4

Year Two Student Content Results

		M		*SD*				
	n	pre	post	pre	post	*t*	*p*	*d*
All students	1676	9.24	16.63	4.39	5.31	41.194	<0.001**	1.52
Middle School	773	7.93	16.76	7.38	5.25	39.180	<0.001**	1.38
High School	565	11.03	16.45	4.53	5.39	9.973	<0.001**	1.09

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 5

Year Three Student Content Results

		M		*SD*				
	N	pre	post	pre	post	*t*	*p*	*d*
All students	1055	11.60	15.99	4.50	5.83	27.302	<0.001**	0.86
Middle School	663	11.28	15.99	4.07	5.91	23.211	<0.001**	0.95
High School	392	12.13	15.96	5.10	5.70	14.696	<0.001**	0.75

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 6

Student Content Results, All Years

		M		*SD*				
	n	pre	post	pre	post	*t*	*p*	*d*
All students	2616	11.38	16.67	4.969	5.828	45.046	<0.001**	0.980
Middle School	1386	9.82	16.37	3.943	5.614	41.607	<0.001**	1.371
High School	1230	13.14	17.00	5.401	6.044	23.191	<0.001**	0.675

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 7

Year One STEM Semantics Survey Results

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	209	94.75	82.24	3.555	<0.001**	0.049
Math	210	89.51	88.54	0.525	0.600	0.002
Engineering	209	88.40	87.39	2.363	0.018*	0.033
Technology	208	90.65	82.05	0.964	0.335	0.001
Careers	208	94.84	84.56	2.459	0.014*	0.021
All Subjects and Careers	210	107.68	92.59	2.314	0.021*	0.013

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 8

Year Two STEM Semantics Results, All Students

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	1125	559.48	521.24	3.448	0.001**	0.007
Math	1117	535.17	531.54	2.378	0.017*	0.006
Engineering	1112	541.38	507.56	0.958	0.338	<0.001
Technology	1116	525.89	504.40	1.497	0.134	0.001
Careers	1108	531.63	509.41	1.804	0.071	0.002
All Subjects and Careers	1125	577.51	535.61	2.382	0.017*	0.002

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 9

Year Two Middle School STEM Semantics Survey Results

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	738	365	338	1.645	0.100	0.001
Math	731	377	321	1.832	0.067	0.006
Engineering	727	339	346	0.700	0.484	<0.001
Technology	732	342	333	1.034	0.301	<0.001
Careers	724	352	320	1.556	0.120	0.002
All Subjects and Careers	738	369	362	1.582	0.114	<0.001

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 10

Year Two High School STEM Semantics Survey Results

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	386	196.54	180.64	3.668	<0.001**	0.031
Math	385	186.17	181.46	1.524	0.128	0.006
Engineering	384	184.82	178.03	0.673	0.501	<0.001
Technology	383	177.36	177.66	1.092	0.275	0.004
Careers	383	188.08	180.68	0.876	0.381	0.001
All Subjects and Careers	386	192.51	190.24	1.961	0.050*	0.012

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 11

Year Three STEM Semantics Survey Results, All Students

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	1028	430.89	465.38	2.229	0.021*	0.002
Math	1021	444.81	430.98	0.786	0.432	<0.001
Engineering	1014	412.73	439.08	2.254	0.024*	0.004
Technology	1013	399.01	398.99	1.935	0.053	0.005
Careers	1000	417.93	419.03	1.053	0.293	0.002
All Subjects and Careers	1028	491.36	519.77	1.617	0.106	0.001

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 12

Year Three Middle School STEM Semantics Survey Results

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	715	295.51	322.91	3.757	<0.001**	0.015
Math	710	314.17	303.47	1.106	0.269	0.001
Engineering	704	288.71	303.47	3.117	0.002**	0.013
Technology	703	272.81	280.14	3.178	0.001**	0.016
Careers	693	286.47	289.38	1.226	0.220	0.002
All Subjects and Careers	715	337.85	364.09	2.648	0.008**	0.006

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 13

Year Three High School STEM Semantics Survey Results

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	313	135.52	142.38	1.530	0.126	0.015
Math	311	131.08	128.01	0.267	0.789	0.001
Engineering	310	134.55	134.44	0.749	0.454	0.002
Technology	310	126.35	118.11	1.343	0.179	0.003
Careers	307	132.53	129.51	0.000	1.000	<0.001
All Subjects and Careers	313	153.02	156.23	1.028	0.304	0.006

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 14

STEM Semantics Survey Results, All Years

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	2362	1092.11	1066.82	2.168	0.030*	0.002
Math	2348	1074.41	1043.27	2.280	0.023*	0.002
Engineering	2335	1052.53	1032.68	0.041	0.967	<0.001
Technology	2337	1019.72	980.73	0.310	0.757	<0.001
Careers	2316	1046.65	1010.67	1.432	0.152	<0.001
All Subjects and Careers	2363	1181.10	1145.25	1.398	0.162	<0.001

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 15

Middle School STEM Semantics Survey Results, All Years

		Mean Ranks				
	N	Positive	Negative	*Z*	*p*	η^2
Science	1453	670.31	655.30	0.930	0.352	0.002
Math	1441	664.02	651.23	2.145	0.032*	0.003
Engineering	1431	654.34	626.41	1.263	0.206	0.003
Technology	1435	628.07	602.39	1.099	0.272	0.003
Careers	1417	634.28	613.70	0.529	0.597	<0.001
All Subjects and Careers	1453	732.54	703.44	0.434	0.665	0.001

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 16

High School STEM Semantics Survey Results, All Years

		Mean Ranks				
	N	Positive	Negative	Z	p	η^2
Science	908	424.82	407.08	4.900	<0.001**	0.028
Math	906	410.21	392.52	0.908	0.364	<0.001
Engineering	903	403.11	402.87	1.749	0.080	0.004
Technology	901	394.75	375.07	2.050	0.040*	0.003
Careers	898	414.01	295.13	1.701	0.089	0.002
All Subjects and Careers	909	452.62	437.91	3.006	0.003*	0.010

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 17

Year One Teacher Results

	Mean Ranks				
Assessment	Positive	Negative	Z	p	η^2
Content	3.50	2.50	0.272	0.785	0.067
STEBI-A Teaching Outcomes	9.00	1.00	1.461	0.144	0.20
STEBI-A Efficacy and Beliefs	0.00	15.00	2.032	0.042*	1.00

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 18

Year Two Teacher Results

Assessment	Mean Ranks: Pretest	Posttest	Post Posttest	X^2	p	η^2
Content	1.86	1.76	2.38	5.158	0.076	0.292
STEBI-A Teaching Outcomes	1.86	2.17	1.98	1.089	0.580	0.020
STEBI-A Efficacy and Beliefs	1.90	2.17	1.93	0.914	0.633	0.022

Note. * significant at 0.05 level and ** significant at 0.01 level.

Table 19

Year Three Teacher Results

Assessment	Mean Ranks: Pretest	Posttest	Post Posttest	X^2	p	η^2
Content	1.39	2.36	2.25	13.65	0.001	0.319
STEBI-A Teaching Outcomes	1.71	2.03	2.26	3.17	0.205	0.083
STEBI-A Efficacy and Beliefs	2.00	2.26	1.74	3.22	0.199	0.085

Note. * significant at 0.05 level and ** significant at 0.01 level.