INQUIRY-BASED SCIENCE: PREPARING HUMAN CAPITAL FOR THE 21ST CENTURY AND BEYOND

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Abstract

High school students need to graduate with 21st century skills to be college and career ready and to be competitive in a global marketplace. A positive trend exists favoring inquiry-based instructional practices that purportedly not only increase science content knowledge, but also 21st century skill development. A suburban school district, Areal Township (pseudonym), implemented an inquiry-based science program based on this trend; however, the degree to which the program has been meeting students’ needs for science content knowledge and 21st century skills development has not been explored. If we were to understand the process by which an inquiry-based science program contributes to attainment of science content and 21st century skill development, then we might be able to improve the delivery of the program and provide a model to be adopted by other schools. Therefore, the purpose of this descriptive case study was to engage with multiple stakeholders to formatively assess the successes and obstacles for helping students to achieve science content and 21st century skills through an inquiry-based curriculum. Using constructivist theory, this study aimed to address the following central research question: How does the implementation of an inquiry-based program within the Areal Township School District (ATSD) support the acquisition of science content knowledge and the development of 21st century skills? This study found that 21st century skill development is embedded in inquiry-based instructional practices. These practices engage students in meaningful learning that spirals in content and is measured using diverse assessments. Time to do inquiry-based science and adequate time for collegial collaboration were obstacles for educators in grades K-5. Other obstacles were turnkey professional development and a lack of ongoing program monitoring, as a result of imposed extrinsic factors from state and federal
mandates. Lastly, it was discovered that not all parts of the curriculum adopted a full inquiry-based approach.

*Key Words*: inquiry-based science, 21st century skills, assessments, professional development, constructivist theory, collaboration, college and career readiness, elementary and middle school science, Next Generation Science Standards (NGSS)
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God, I will “not rest on my laurels”. Thank you Rev. Dr. Cory Jones for those words of inspiration.
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Chapter One: Introduction

High school students need to graduate with 21st century skills in order to be college and career ready and to be competitive in a global marketplace. Twenty-first century skills — critical thinking and problem solving, creativity and innovation, collaboration, and communication — are essential to student success (Bellanca & Brandt, 2010) and are vital parts of inquiry (NGSS Lead States, 2013c). Science has been identified as a key subject through which the development of these skills and corresponding practices can occur (Hilton, 2010). According to Minner, Levy, and Century (2010), a meta-analysis of 138 studies indicates a clear, positive trend favoring inquiry-based instructional practices that purportedly not only increase science content knowledge, but also critical thinking and problem solving skills.

Statement of the Problem

In 2005, Areal Township School District (ATSD) recognized the need to improve science instruction and learning, which resulted in transforming its approach to curriculum in Grades K-8 from traditional methods of teaching science to inquiry-based instruction. For the purpose of this study, the traditional approach is understood as “teacher-led, textbook” instruction. Teacher-led, textbook instruction is, using textbooks under the direct guidance of the teacher and students are not given the opportunity to explore science on their own. Inquiry-based science instruction, meanwhile, is hands-on and student-centered, with the teacher’s role being to facilitate learning while students are actively engaged in inquiry.

Findings show that students learn science more effectively when they actively engage in the practices of science. In addition, a quality, integrated learning experience incorporating both practice and content leads not only to greater mastery, but importantly, also to a deeper interest
in science (as cited in NGSS Lead States, 2013c). In ATSD, standardized test scores at Grade 4 and Grade 8 have been traditionally used as the only indicators to monitor science achievement.

Inquiry-based science and the development of 21st century skills and practices were explored through this descriptive case study in order to understand the process through which a K-8 inquiry-based science program prepares students with content knowledge, while simultaneously developing essential skills for college and career readiness, thus promoting 21st century citizenship. The central phenomenon, an inquiry-based program, is generally understood as more student centered than a traditional, top-down teaching approach; more details on each method are provided in subsequent sections of the dissertation.

The degree to which this curriculum is meeting the goals for content and practices inclusive of 21st century skills development, as well as its alignment with Next Generation Science Standards (NGSS), needed to be explored in order to guide learning and instruction. Such practices include exploring the learning environment, student motivation and engagement, assessments, and the professional development of teachers regarding inquiry-based science instruction. Acquiring a deeper understanding of this process, including obstacles as well as challenges, from multiple perspectives, can lead to an explanation of how an inquiry-based science program contributes the attainment of science content and 21st century skill development.

Findings from this study can be used to improve ATSD’s inquiry-based program and can possibly be used as an exemplar for other schools, considering the impetus to prepare students for college and career using an inquiry-based science program. Therefore, the purpose of this descriptive case study was to engage with multiple stakeholders to formatively assess the successes and obstacles arising as students seek to achieve science content and 21st century skills through an inquiry-based curriculum. Administrators and teachers within ATSD participated in
this study to provide insights into the process, implementation, and outcomes of its K-8 inquiry-based science program.

All students should be college and career ready, thus prepared for citizenship. As a science educator, it is of utmost importance to ensure that these goals are met. The National Science Teachers Association (NSTA), NGSS Lead States, and other researchers in the field have clearly stated the importance of meeting these goals. Greenstein (2012) stated, “To succeed in today’s world, students need to master core skills and knowledge. They also need the skills necessary for personal and career success. In blending the two together, the core is honored and the 21st century skills are embedded” (p. 17).

NSTA (2011) has claimed that an exemplary science education can offer a rich context for developing many 21st century skills that contribute to a well-prepared workforce for the future and individual life skills that help individuals succeed (p. 1); in this context, skills and content are equally important for college and career readiness, and marrying the two increases student learning and also raises the level of content rigor (NGSS). A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (Framework), which formed the basis for developing NGSS, emphasized that learning is defined as the combination of both knowledge and practice; there are not separate content and process learning goals (Standards & National Research Council, 2012, p. 254).

Ultimately, there is no way of knowing how well the program at ATSD has been meeting these goals without formatively assessing it in terms of the fidelity of instruction, on both content and 21st century skill development, as well as the degree to which it is aligned with NGSS. Identifying and sharing the obstacles and opportunities arising from the implementation of the inquiry-based program at ATSD may assist other districts in developing similar types of programs.
There is a gap in empirical data on how 21st century skills are assessed in inquiry-based learning of science content. Having been made aware of this gap, the Assessment and Teaching of 21st Century Skills (ATC21S) project (Griffin, McGaw, & Care, 2012) set a goal:

To explore the teaching implications of twenty-first century skills, the project worked closely with teachers, education systems, governments and global organizations represented on the project board and advisory panel in order to link these skills both to new areas of curriculum and to existing discipline-based key learning areas. (p.15)

The overarching goal of the ATC21S project was to establish a method to include assessment of 21st century skills into curricula along with ways to measure them.

In addition, there is a lack of qualitative data on inquiry-based programs that have been in existence for as long as the program implemented at ATSD, and on inquiry-based programs in general where content is combined with 21st century skills and goals that not only increase science content knowledge, but that also prepare students for college and career readiness. In view of these deficiencies in evidence, this study sought to not only fill a gap in practice, but to also add to the growing body of literature on elementary school inquiry-based science programs.

This study was intended to benefit many audiences: teachers, curriculum developers, science supervisors, 21st century skills advocates, administrators, and any other stakeholders who are involved with science, education, 21st century skills learning, global education, and/or guidance and decision-making for preparing students for college and career readiness. It provides the audience with a blueprint for implementing an inquiry-based science program, within the new NGSS framework, outlining how essential skills for the 21st century can be learned for college and career readiness though the simultaneous acquisition of content knowledge.
Furthermore, because these skills have been identified as those needed for work, school, and life within a global economy (Partnership for 21st Century Learning 2009, June), discourse in the literature has focused on college and career readiness skills for both students planning to attend four-year colleges for those heading to trade schools or seeking entry level jobs. As a result, this research adds to contemporary conversations within communities of practice, as well as to scholarly literature. There is a copious amount of literature on what needs to be done; however, the literature lacks adequate empirical studies on how to accomplish this mission for all students.

**Significance of Research Problem**

The significance of this research crosses several levels of analysis—local, national, and global. Locally, the present goals of ATSD are to “continue to align and evaluate instructional practices…and curricula with 21st century skills and assessment, as well as advancing STEM (Science Technology, Engineering, and Math) initiatives” (ATSD 2014-15 All Students Achieving Plan). For science, these goals mean teachers are charged with planning to ensure that 21st century skills and assessment undergird instruction and learning. When considering the advancement of STEM as essential for college and career readiness, this research can provide a resourceful tool school leaders can use as a baseline for implementing similar programs. The broader endpoint is to ensure that science instruction and practices are not stagnant, but are advancing to meet societal demands. On the other hand, while developing means to meet these goals locally, teachers are challenged with extrinsic changes taking place nationally that also impact how they prepare students for 21st century citizenship, for example, the NGSS and the Partnership for Assessment of Readiness for College and Career (PARCC).

Nationally, the adoption of the NGSS by states will add to the upheaval, as many states
are still grappling to develop curricula capable of increasing science achievement. This adoption creates a need for more schools to know how to integrate rigorous content and science and engineering practices in order to fulfill the vision of NGSS. These standards delineate the importance of preparing students with knowledge and the use of this knowledge in order to meet the nation’s needs and to cohere with its values (NGSS Lead States, 2013a). This study can serve as a model for state programs, particularly for many schools that have not advanced beyond the initial stage of curriculum development to meet the goal of increasing science achievement.

PARCC is the driving force for assessing problem solving and critical thinking skills for English language arts/literacy and mathematics.

PARCC uses five performance level descriptors (PLDs) as a tool to assess this claim. According to PARCC policy claims, a student on level four has a strong command of knowledge, skills, and practices embodied in Common Core Content Standards (CCCS) for academic readiness to move to next grade level ("Partnership for Assessment of Readiness for College and Careers," 2012). Therefore, by honing these 21st century skills in science, the results of this study can potentially help to serve students in three ways. First, students will be better prepared to achieve in math and language arts because NGSS and PARCC are connected to CCCS; second, students will be better prepared for college and career; and third, by meeting those goals, students will be better prepared to meet the demands of a global economy.

Addressing the significance of this research on the global level, international comparisons show learning gains in the United States in the fourth grade are not being sustained into eighth grade; there, mathematics and science achievement failed to measurably improve (Duncan, 2012). It has been a little over 30 years since A Nation at Risk was first published by
the National Commission on Excellence in Education. This report sparked an outcry for educational reform, although the movement initially began over 50 years ago and was coined the Sputnik era. During this era, the United States competed against the former Soviet Union to become the world leader in science advancements. A Nation at Risk reported that the United States trailed other countries in science and innovation, and these areas needed much improvement if the United States were to keep a competitive edge (United States. National Commission on Excellence in Education., 1983). In 32 years, the United States has not made any significant progress in closing the achievement gap with other nations. According to data from Trends in Mathematical and Science Studies (TIMSS, 2012) for 2011, the United States still lags behind; other countries are outperforming the United States ("TIMSS 2011 Assessment," 2012). These results indicate the need for urgent change in how schools in the United States teach STEM through inquiry-based approaches. Science achievement and practices have been brought to the forefront in evaluations and discussions of educational reforms needed to sustain U.S. prominence in the global economy.

Justifiably, “educational and professional groups are increasingly attentive to 21st century skills as they update their curricula, policies, and practices. The Educational Testing Service, the International Society for Technology Education, and the U.S. Department of Labor’s Secretary’s Commission on Achieving the Necessary Skills are thoughtfully engaged in dialogue” (Greenstein, 2012, p. 21). On all three levels, it has been established that rigorous science content and practices are needed to meet societal demands. This study at the local level may have an impact on the aforesaid boundaries. If the students are prepared locally from instruction that is aligned with NGSS, which also embraces STEM education, then globally, our students will be college and career ready and internationally competitive.
Understanding how 21st century skills are developed through pedagogies of inquiry-based instruction that include project and problem based learning is a current priority for scholars, government officials, and practitioners alike. Therefore, the results of this study could be beneficial in moving the ATSD forward and could help to provide blueprints for districts nationally to help them also prepare all students to be successful 21st century citizens.

**Positionality Statement**

It is my belief that all students can learn science and feel success. My biases and perspectives need to be shared in order diminish a threat to internal validity. This validity is discussed in the trustworthiness section of the proposal.

My biases, that all students can develop and deepen their critical thinking and problem solving skills through the learning of inquiry-based science, are what drove me to choose a topic that had yet to be explored through an academic study in this district.

The adoption of a new curriculum changed my position as an elementary school science lab teacher. At the time, I did not understand that a different approach to instruction could be better for the students coming to a science lab to learn science, particularly considering the fact that the teachers at the elementary school did not have sufficient time to teach it. It was not until after I attended training that I understood the difference between “teacher-led” instruction and student-centered, inquiry-based instruction. As a result, I became a supporter of inquiry-based instruction.

I believe that 21st century skills must be a part of the curriculum; however, much more clarity is needed to understand how they can be developed, deepened, and achieved for all students.
My research may be impacted by my cultural sensitivity when collecting and interpreting data. I am aware of the political and societal imperatives to close the achievement gap; it is of particular importance to me as the parent of a special needs son.

Discerning that some teacher educational preparation does not prepare general education teachers in science adequately may prevent me from fully understanding my research population. Even though this study does not focus on teacher preparation, it is my belief that an important aspect of designing inquiry-based instruction is to have an impact on equity in student achievement. Because I wanted to learn more about inquiry-based science teaching, I expected my colleagues would be equally interested; I believed all teachers should be flexible and ready to learn new things. Considering this positionality, the penultimate section of Chapter Three outlines how all biases and threats to validity are reduced. Lastly, conducting this research has moved me from what may have been complacency regarding science achievement to an advocate for informed change.

**Research Central Questions and Sub-questions**

The overarching question for this study was: How does the implementation of an inquiry-based program within Areal Township School District (ATSD) support the acquisition of science content knowledge and the development of 21st century skills? In addition to the central question, three sub questions also guided this study:

1. What was the rationale for the program?
2. How well did the program meet its desired goals?
3. What was the transition process like?
Theoretical Framework

Constructivist theory was used to deconstruct and understand this problem of practice. Constructivism commonly refers to the theory that understands learning as a process of active participation between people and their experiences (Lee Yuen, 2010, p. 10). “Constructivism is a philosophical view or perspective on how knowledge is acquired and how individuals construct knowledge to make sense of their world” (Matson & Parsons, 2006, p. 1).

Bruner’s Framework

This study will use the theoretical framework of Jerome Bruner, one of the founding fathers of constructivist theory; some of the many other perspectives on this theory will be explained in a subsequent chapter. Bruner’s theory postulated that individuals construct knowledge and interpret the world mostly in terms of similarities and differences (Cooper, 2013). As outlined by Cooper (2013), three characteristics of effective instruction were used to see how well the program aligns with Bruner’s ideas:

- Instruction should relate to experiences and contexts to make the student willing and able to learn (Culatta, 2013), resulting in a readiness to learn.

- Content should be structured so it can be most easily grasped by the learner (Cooper, 2013). “Bruner defined structure in terms of fundamental disciplinary ideas, concepts, and relationships” (Deng & Luke, 2008, p. 75). Bruner argued, “Grasping the structure of a subject is understanding it in a way that permits many other things to be related to it meaningfully” (as cited in Deng & Luke, 2008, p. 75). This translation of subject matter is directly related to the learner’s cognitive development (Deng & Luke, 2008, p. 75). The idea of structure is emphasized in inquiry and problem solving curricula that focus on in-depth exploration of
smaller, illustrative units of content that allow generalizations (Franklin & Johnson, 2008, p. 463).

- Instruction should be sequenced. Bruner referred to this sequencing as a spiral curriculum. A spiral curriculum is one through which a subject, topic, or theme is revisited several times; the complexity of the topic increases with each visit so the new learning is connected to the old learning (Gibbs, 2014, p. 41).

Expansions on Bruner

Bruner initially asserted, however, that this learning could be done intrinsically. He expanded his theoretical framework to include the social and cultural aspects of learning (Culatta, 2013) after being influenced by the work of Lev Vygotsky, who shared Bruner's idea that a child's social environment and social interactions are key elements of the learning process (Firestone, 2014). This inclusion underlies the assumption that communication and collaboration are fundamental to learning. In an inquiry-based classroom where teachers facilitate learning and students learn from their peers in groups, this social view of constructivism will enable a better understanding of the role that inquiry-based instruction has on promoting essential 21st century skills. Importantly, this theory has been used in many studies in science across grade levels (Etuk, Etuk, Etudor-Eyo, & Samuel, 2011; Lee Yuen, 2010; Tosa, 2011). In addition, Gibbons (2003) cited constructivist theory as the dominant theory in elementary science teaching and learning (Martin, Sexton, Franklin, & Gerlovich, 1997).

Inquiry-based instruction, which is grounded in this theory, has been the pedagogical focus for a decade in ATSD. Consequently, this study provided a rich context to explore the rationale for using this theory in practice. Inquiry-based instruction widens student engagement in the learning process from elementary to middle school; it allows student to progressively build
on prior knowledge and apply it to “make sense of their world” — an inherent skill of problem solving in the constructivist perspective.

Constructivist theory provided an analytical lens for a holistic approach to deconstructing and understanding this problem of practice. To answer the research questions from multiple perspectives, this theory was used to explore process, implementation, and outcomes of the inquiry-based program.
Chapter Two: Literature Review

This study focused on one suburban school District exploring how the school prepares students with the requisite 21st century skills, in addition to science content knowledge, using an inquiry-based science program. Understanding how 21st century skills are developed through pedagogy of inquiry, which can include project and problem-based learning, is a current phenomenon with implications across levels of analysis—local, national, and global—yet it is unresolved. This literature review begins by examining the roles of the NGSS and the Partnership for 21st Century Learning (P21) in the current state of science education. It specifically examines three claims: (a) 21st century learning involves the development of skills that prepare all students for college and career readiness; (b) constructivist, inquiry-based instruction increases achievement of all students; and (c) the key features of inquiry-based teaching and instruction that have been shown to be effective in project-based learning and problem-based learning are teacher-student roles, professional development, and time.

Chapter Organization

The purpose of this study was to engage with multiple stakeholders at ATSD to formatively assess the successes and obstacles for helping students to learn science content knowledge and 21st century skills through an inquiry-based curriculum. Therefore, to widen the lens of present scholarship and to frame this study, the subsequent sections of this review examine the NGSS and P21 frameworks and each of the aforementioned claims. The chapter concludes with a summary of the reviewed body of literature.
Current State of Science Education

A review of the NGSS and the P21 is imperative in order to understand the expectations these frameworks have set forth to produce citizens who are well-equipped for the 21st century and beyond and to define why inquiry-based instruction is key. The researcher found it essential to underscore these frameworks to explore 21st-century learning, content rigor, and integration of science and engineering practices (SEPs) for meeting performance expectations (PEs). The following section is an overview of the concepts outlined in the NGSS followed by those included in the P21.

Next Generation Science Standards (NGSS)

The standards movement began decades before the adoption of the NGSS and involved a process of political debates about whether or not national standards should be created to determine what students need to know and be able to do. This movement emerged from supportive national entities and education reports, as described in the succeeding paragraphs. Four national reports on education were integral to the standards debates: A Nation at Risk, Science for All Americans, The Opportunity Equation, and How People Learn (Banko, Grant, Jabot, McCormack, & O'Brien, 2013). A Nation at Risk, which was previously mentioned in the introduction of this study, was the first call for education reform. This 1983 report was instrumental in the discussion of the changes that would be needed for students to be educated in a way that would allow the United States to maintain its global and competitive economic edge. The same challenges still face the U.S. education system, 33 years later. The National Council of Teachers of Mathematics (NCTM) standards were widely accepted and were used to outline benchmarks for what students should know in science, mathematics, and technology; this process
was directed by a panel which produced the report, *Science for All Americans*, in 1989 (Banko et al., 2013).

This report described a standard of science literacy for all students, but it did not outline what should be taught at any particular grade level or in specific courses (Project 2061 (American Association for the Advancement of Science), 1989). A little more than three years later, however, a separate document, *Benchmarks for Science Literacy*, was published; it complemented *Science for All Americans* by adding specific learning goals. It stated what students should know and be able to do at the end of grades 2, 5, 8, and 12 (Project 2061 (American Association for the Advancement of Science), 1993). Subsequently, the interest in national standards and assessments began to develop.

As a result of Congressional legislation, The National Council on Education Standards and Tests (NCEST) was created and charged with studying the “desirability and feasibility” of national standards and assessments. The NCEST study resulted in an endorsement for high standards and assessments directed at promoting educational equity, preserving democracy, enhancing civic culture, and improving economic competitiveness (Banko et al., 2013, p. 21). The study’s authors also recommended the creation of the National Education Standards and Assessment Council to oversee the development and implementation of standards and assessments (Banko et al., 2013, p. 21). However, despite the involvement of a national entity, the standards did not progress further until the president of the National Science Teachers Association (NSTA) reached out to the president of the National Academy of Sciences, a process that led to the involvement of the National Research Council (NRC) in the development of the National Science Education Standards (NSES) in 1996 (Banko et al., 2013, p. 22). The standards went beyond simply outlining the content that students should learn include standards for
teachers, professional development, assessment, science programs, and systems (Banko et al., 2013, p. 22). It is worth noting that voluntary national tests “to measure students in any part of the country against national standards” was proposed by President Bill Clinton in 1997; this measure was stalled because it failed to receive bipartisan support (Banko et al., 2013, p. 24).

A few years later in 2002, President George W. Bush decided to revamp and reauthorize the Elementary and Secondary Education Act (ESEA), which led to the creation of the No Child Left Behind (NCLB) reform act. The intended purpose of NCLB was to ensure that all students met specified learning goals and that all schools made adequate yearly progress. Unlike ESEA, the federal government has a dominant role in guaranteeing that NCLB is fulfilled.

Paradoxically, the National Assessment of Educational Progress (NAEP), the nation’s common metric tool for measuring what American students should know and be able to do in various subjects, revealed flaws in NCLB. Results from this assessment disclosed three trends: (a) “proficiency,” the level that determines whether students are effectively educated at a specific grade level, does not mean the same thing in all states; (b) the content students were expected to know varied widely, even within states; and (c) no commonality amongst states would show that national standards were being used (Banko et al., 2013). These flaws pointed to a need for common standards, particularly when considering evidence from the Programme for International Students Assessment (PISA) and Trends in International Mathematics and Science Studies (TIMSS) that showed students in other nations outperforming students in the United States.

Common standards began to gain national support after a commission was convened by the Carnegie Corporation citing the need for the nation to adopt more rigorous standards in mathematics and science. Considering the previous political debates and the defeat of national
standards initiatives, the Council of Chief State School Officers (CCSO) and the National Governors Association (NGA) led the effort at the state level, unlike NCLB, which was spearheaded by the federal government. This led to the commitment that states would support the development of common assessments to measure progress toward standards (Banko et al., 2013, p. 29). State leaders began to develop the common core standards for English language arts [ELA]/literacy and mathematics in 2009; the standards were released in 2011 by the NGA’s Center for Best Practices and the Council of Chief State School Officers (CCSSO). Interestingly, these standards included college and career readiness standards that were actually developed first; the K-12 standards were incorporated later into what is known today as the Common Core Standards (CCS) (Core Common Standards, 2014). The development of these standards was a national effort with feedback from teachers, parents, school administrators, and the public. As of April 2016, 43 states, the District of Columbia, four territories, and the Department of Defense Education Activity (DoDEA) have adopted the CCS, implementing them according to their own timelines (Core Common Standards, 2014). The purpose of these standards is to ensure that students are ready for success after high school by providing consistent guidelines on what students need to know and be able to do in ELA/literacy and mathematics; it was believed that the process of collaboration and feedback received from the many stakeholders would ensure this goal. Using the CCS initiative as a springboard, the subsequent Opportunity Equation report determined that the adoption of more rigorous common standards in science was needed ("Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy," 2009)

A Commission created by Carnegie Corporation and the Institute for Advanced Study consisting of members from diverse backgrounds wrote the Opportunity Equation report after
being charged with assessing the current state of math and science and developing
recommendations to inspire action ("Opportunity Equation: Transforming Mathematics and
Science Education for Citizenship and the Global Economy," 2009). Here is a summary of a few
of the recommendations that served as building blocks for the NGSS.

First, the Commission stated that the process should emphasize enabling students to
develop the competencies that characterize scientific thinking and a more thorough
understanding of foundational concepts and theories to provide a baseline for scientific literacy
and to serve as the basis for further studies (Banko et al., 2013, p. 26). It was determined that
standards should be written to counteract covering too many concepts with too little depth. This
step, to focus on core disciplinary ideas, was critical in the revision of NSES.

Further, the Commission established that classroom assessment was essential to increase
student achievement, which would be “linked to new fewer, clearer, higher standards” and that
teachers needed to be provided with feedback to improve instruction and to compile information
about student learning (Banko et al., 2013, p. 28). The report highlighted several reasons for
common standards in science. Lastly, it was also reported that recruitment and retaining of well-
prepared teachers and effective ongoing professional learning would not only change
pedagogical practices, but would also increase the learning of science. This report was released
in 2009 as the development of the NGSS was underway.

Several sources on cognitive science played pivotal roles in the development of the
NGSS: How People Learn (National Research Council, 1999); How Students Learn (National
Research Council, Donovan, & Bransford, 2005); Taking Science to School (National Research
Council, 2007); and Education for Life and Work (National Research Council, 2012)
(http://www.nextgenscience.org/). Below are highlights of each report:
How People Learn (Bransford, Brown, Cocking, & National Research Council (U.S.), 1999) highlighted that people are active learners and construct knowledge by building on prior knowledge. It proposed that a meta-cognitive approach to teaching would help students take charge of their learning by defining goals and monitoring how they achieve them. It also stated that an in-depth learning of subject matter can be obtained by building on a concept beyond a single year. How Students Learn (National Research Council, 2005), meanwhile, summarized that students learn science through inquiry. It dispelled the scientific method as a step by step process to learning science by stating that it “shortchanges observation, imagination and reasoning” (p. 405). Taking Science to School (R. A. Duschl et al., 2007) stressed the need to bring a much broader cohort of students to much higher levels of achievement in science. It identified four strands of science proficiency: knowing, using, and interpreting scientific explanations of the natural world; generating and evaluating scientific evidence and explanations; understanding the nature and development of scientific knowledge; and participating productively in scientific practices and discourse. Its support for common and rigorous standards and aligned assessments and for targeted professional development in science teaching cohered with the Commission’s focus on bringing all students to much higher levels of science knowledge and understanding and producing a STEM-literate citizenry. Finally, Education for Life and Work Developing Transferable Knowledge and Skills in the 21st Century (National Resource Council, 2012) highlighted content (facts, formulas, concepts, theories) and process (scientific method, inquiry, discourse) related to a need to articulate what is meant by scientific inquiry when the call was to have more inquiry in the classroom.
The highlights of these reports were “central” to the development of the NRC (National Research Council) Framework that was released in July 2011. The NRC Framework committee was composed of nationally and internationally known scientists, two Nobel Laureates, cognitive scientists, science education researchers, and science education standards and policy experts. A design team with representatives from physical science, life science, earth/space science, and engineering developed the framework. A draft was released to the public for feedback before final approval by the NRC. The next step was to develop national standards, and this effort was managed by Achieve, Inc.

Modeling after the success of the Common Core Standards, the states led in the development of the NGSS. Likewise, this process used public feedback and was collaborative. In addition to the states, other stakeholders included science education, higher education, and industry. A final review of the draft revealed that the NGSS are performance expectations that are consistent with the content and structure of the Framework and are internationally benchmarked against other countries whose students perform well in math and science. Taken as a whole, the United States finally established national standards or goals in science that:

reflect what a student should know and be able to do—they do not dictate the manner or methods by which the standards are taught. The performance expectations are written in a way that expresses the concept and skills to be performed but still leaves curricular and instructional decisions to states, districts, school and teachers. (NGSS Lead States, 2013b, p. 2)

NGSS (2013a) clearly states that its focus is on performance and not curriculum or instruction, while emphasizing the importance of quality instruction and materials to meet the performance expectations, thus giving teachers flexibility. Considering this emphasis, this concept can be
used to learn about the teachers’ role in preparing lessons in order to explore how students acquire knowledge through inquiry. According to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* 2012), there are three dimensions that would allow students to achieve a high quality science education with a focus on rigor: (a) practices that include how students conduct inquiry such as models, arguments, and explanations’; (b) crosscutting concepts (CC) where ideas and practice cut across science disciplines; and (c) science and engineer disciplinary core ideas (DCI) that are learnable over multiple grades at increasing depth. This specific vision of the NGSS *Framework for K-12 Science Education* was used to compare the implementation of these dimensions in practice that involve student engagement and teacher instruction in inquiry.

**The Partnership for 21st Century Learning (P21)**

Additionally, the Partnership for 21st Century Learning (P21) (Partnership for 21st Century Learning, 2009) was essential to the process of establishing standards. It brought together

a coalition of the business community, education leaders, and policymakers whose mission is to bring 21st century readiness to the center of U.S. K-12 education and to kick-start a national conversation on the importance of 21st century skills for all students. (Partnership for 21st Century Learning, n.d.)

Its website further outlines the role of P21:

P21 was instrumental in the joint establishment of comprehensive skills, along with content mastery, that all sectors agreed to be essential for success. In addition, it took years to develop this framework for 21st century learning and has since been recognized as the model to infuse 21st century skills into the curriculum. This Framework has been
adopted by hundreds of educational agencies and organizations formally or informally
guide learning communities, integration of these skills into the curriculum, and
professional development. (Partnership for 21st Century Learning, n.d.)

Delineated in this framework is a support system that is needed for students to master 21st
century skills for learning and innovation. Importantly, science is listed as one of the core
subjects that students need to master in order to gain entry into college and careers (Partnership
for 21st Century Learning, 2009, June). This system consists of five elements to ensure the
mastery of skills: (a) 21st century standards; (b) assessment of 21st century skills; (c) 21st century
curriculum and instruction; (d) 21st professional development; and (e) 21st century learning
environment (Partnership for 21st Century Learning, 2009, June). This concept was applied to
this study to deconstruct the endpoint—the inquiry-based program as it relates instruction and
student attainment of these readiness skills for college, career, and life.

The following section widens the lens on why inquiry-based instruction is the most
effective form of teaching for all students and explains how it prepares all students with content
knowledge, practices, and 21st century skills by using the previously stated claims: (a) 21st
century learning incorporates skills that prepare all students for college and career readiness; (b)
constructivist, inquiry-based instruction increases achievement of all students; and (c) the key
features of inquiry-based teaching and instruction that have been shown to be effective in
project-based learning and problem-based learning are teacher-student roles, professional
development, and time, respectively.

21st Century Skills Prepare Students for College and Career Readiness

With the aim of understanding that 21st century skills are skills that prepare students for
college and career readiness, it is imperative to first understand what these essential skills are.
P21 will be used as the reference to understand this. According to P21 (2009), these skills are creativity, innovation, critical thinking, problem solving, communication, and collaboration. The definitions of these skills are broad; the following table summarizes them.
<table>
<thead>
<tr>
<th>Skill</th>
<th>Definition</th>
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| **Creativity**   | **Think Creatively**  
|                  | • Use a wide range of idea creation techniques (such as brainstorming)  
|                  | • Create new and worthwhile ideas (both incremental and radical concepts)  
|                  | • Elaborate, refine, analyze and evaluate ideas in order to improve and maximize creative efforts  
|                  | **Work Creatively With Others**  
|                  | • Develop, implement and communicate new ideas to others effectively  
|                  | • Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work  
|                  | • Demonstrate originality and inventiveness in work and understand the real-world limits to adopting new ideas  
|                  | • View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes  
| Innovation       | **Implement Innovations**  
|                  | • Act on creative ideas to make a tangible and useful contribution to the field in which the innovation will occur  
| **Critical thinking** | **Reason Effectively**  
|                  | • Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation  
|                  | **Use Systems Thinking**  
|                  | • Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems  
|                  | **Make Judgments and Decisions**  
|                  | • Effectively analyze and evaluate evidence, arguments, claims and beliefs  
|                  | • Analyze and evaluate major alternative points of view  
|                  | • Synthesize and make connections between information and arguments  
|                  | • Interpret information and draw conclusions based on the best analysis  
|                  | • Reflect critically on learning experiences and processes  
| **Problem Solving** | **Solve Problems**  
|                  | • Solve different kinds of non-familiar problems in both conventional and innovative ways  
|                  | • Identify and ask significant questions that clarify various points of view and lead to better solutions  
| **Communication** | **Communicate Clearly**  
|                  | • Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts  
|                  | • Listen effectively to decipher meaning, including knowledge, values, attitudes and intentions  
|                  | • Use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade)  
|                  | • Utilize multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact  
|                  | • Communicate effectively in diverse environments (including multi-lingual)  
| **Collaboration** | **Collaborate with Others**  
|                  | • Demonstrate ability to work effectively and respectfully with diverse teams  
|                  | • Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal  
|                  | • Assume shared responsibility for collaborative work, and value the individual contributions made by each team member  

*Source: (Partnership for 21st Century Learning, 2009)*
Although broadly defined, if learned and developed these skills are applicable to college and career, as well as life. Secondly, it is also necessary to define college and career readiness to further understand this claim. Greenstein (2012) defines them as follows: “College ready is having the academic skills, abilities, and attributes to be prepared for any post-secondary education, and career ready is having the knowledge, skills, and qualities to succeed in a career” (p. 158).

Yet, when considering the importance of these skills along with the goals of preparing students for college and career, and whether or not one skill is more fundamental than another, P21 clarifies that a “focus on creativity, critical thinking, communication and collaboration is essential to prepare students for the future.” However, this requires a “blend of these specific skills, content knowledge, expertise and literacies” (http://www.p21.org/our-work/p21-framework). This blend is what is important; it is what employers are looking for in a flat economy.

The structure of the workplace has changed over the years to include skills as well as competencies, or the ability to apply the skills in complex situations. “Firms have restructured and eliminated layers of management...increased demand for a particular kind of problem solving...innovative solutions that work” (Hilton, 2010, p. 14), and the United States economy is getting stronger (Goldman Sachs, 2014; Schneider, 2015). However, before this upscaling, businesses were not doing less, the people were doing more and continue to do more to accomplish the companies’ goals and objectives (Hodge & Lear, 2011, p. 30). It is evident that there is a need for all students to be equipped with these blended skills in order to meet workplace demands. Employers seek people who have mastered these skills, particularly in the STEM field. “Those people who can contribute to the workplace through responsibility, time
management, and goal orientation will be the most successful” (Greenstein, 2012, p. 159).

Having recognized that these blended skills are crucial in the workplace, companies are working with educators and researchers to determine how to assess these skill sets for career readiness. According to Griffin, et al. (2012):

Cisco, Intel, and Microsoft joined forces to sponsor an international, multi-year project to define skills required in their operational terms and to address... barriers to their ICT based assessments in ways that take into account assessment needs from classroom practice to national and international studies on student achievement (pp. 1-2).

Businesses working with educational organizations provide evidence that employers know what they are looking for in a flat, global economy, which is why it is imperative to assess students for 21st century skills development.

Considering this need, several educational organizations have identified ways to assess 21st century skills development, as well as its mastery for college and career. First, EdLeader21, which consists of over 70 member schools and districts nationwide, has developed a 4C’s rubric to assess critical thinking, creativity, communication, and collaboration skills. This rubric, however, is for purchase only (EdLeader21, 2012) and its success is unknown but worth noting, particularly since assessments of 21st century skills are still evolving.

There are, however, formative assessments, such as the previously mentioned PISA published by the Organisation for Economic Co-operation and Development (OECD, year). PISA is a “digital test that assesses higher order thinking and other 21st century skills” (Partnership for 21st Century Learning, 2009, June) that has been in use for over a decade. According to the OECD, PISA began in 2000 and is given every three years to 15-year-olds in various countries to provide comparisons of students’ performance over time and to assess the
impact of education policy decisions (Organisation for Economic-Co-operation and Development (OECD), 2011). Interestingly, there is now a PISA test for schools, which is currently available in the United States (OECD, 2011). Considering global competitiveness, seemingly, this would be the assessment to use. Contrarily, according to P21, the United States Department of Education has funded two consortia of states to develop assessments for 21st century skills as well as content in mathematics and ELA/ literacy: Partnership for Assessment of Readiness for College and Career (PARCC) and SMARTER Balance.

PARCC is newly developed. It was piloted by many school districts before being administered in 2014-15 only, however, in the 13 states that make up PARCC ("Partnership for Assessment of Readiness for College and Careers," 2012). It is still in the developmental and research phases. Despite being nascent, it has an assessment tool to measure the mastery of content as well as problem solving and critical thinking 21st century skills. The tool was adopted by the PARCC Governing Board and Advisory Committee on College Readiness. Assessments are aligned with the rigorous Common Core Content Standards (CCCS) and were developed using policy level descriptors adopted as a guide. PARCC describes this assessment tool as performance level descriptors (PLDs) which determine whether students have achieved content knowledge, skills, and practices at each grade level, and when tested in high school, college and career readiness, which is level four at all grade levels in math and ELA ("Partnership for Assessment of Readiness for College and Careers," 2012). As a result, the PARCC assessment will be used to determine what all students need for them be successful in college for STEM majors as well as non-STEM majors.

Furthermore, there is a need for STEM majors. STEM education is of great importance to the United States because “it will determine if the United States remains a leader amongst
nations, whether we are prepared to solve challenges in the areas of energy, health, environmental protection and nation security” (President's Council of Advisors on Science and Technology (PCAST), 2010, p. 42). However, “all students—whether or not they pursue careers in science, technology, engineering, or math—will be consumers of news and information on STEM issues that will directly affect their lives” (Fisher & Frey, 2014, p. 86). In other words, all students need to possess 21st century skills that can be learned in all majors to understand and challenge complex STEM issues if a significant level of economic equality and global competitiveness is to be reached (Fisher & Frey, 2014; National Academy of Engineering & National Research Council, 2014; “Partnership for Assessment of Readiness for College and Careers,” 2012; Saavedra & Opfer, 2012; Stage & Kinzie, 2009). Regardless of the academic major, science plays a pivotal role in developing these much needed skills (Duran & Sendag, 2012; Jones, 2014; NGSS Lead States, 2013c; Partnership for 21st Century Learning, 2009).

A study by Assefa and Gershman (2012) revealed that 21st century skills are embedded in science education. Objectives and activities from 38 lesson plans were analysed, and it consistently found that word association with 21st century skills was present using content analysis on T-Lab software as the methodological approach. The study concluded: “Despite limitations of the method employed and the number of lesson plans...the results showed significant patterns and relationship in the way that 21st century skills are weaved into science content lessons” (p. 153).

Responding to a need to develop these skills, science is seen as a promising context for this purpose (Hilton, 2010; NGSS Lead States, 2013c; NSTA Board of Directors, 2011; Partnership for 21st Century Learning, 2009). In school, as well as in out of school programs (e.g., NASA Education, Project Tomorrow, and Project Lead the Way), STEM interest is
promoted simultaneously with the development of 21\textsuperscript{st} century skills. Such programs can be considered paradigms because they involve the marrying of 21\textsuperscript{st} century skills development with inquiry-based learning.

Inquiry-based learning allows students to ask questions, observe, experiment, and communicate by taking part in lessons that are hands-on, real world, and collaborative. This approach fosters 21\textsuperscript{st} century skills, such as innovation, critical thinking, and problem-solving (Barell, 2012; Bell, 2010; Bender, 2012; Jones, 2014). As the next section addresses, if this approach is successfully implemented, it can benefit all students.

**Constructivist, Inquiry-Based Instruction Increases Achievement of All Students**

As mentioned in Chapter One, there are many perspectives on constructivist, inquiry-based instruction; therefore, constructivism and inquiry-based instruction are key terms that require definition as they relate to this particular study. Constructivism commonly refers to the theory that understands learning as a process of active participation between people and their experiences. In other words, “constructivism is a philosophical view or perspective on how knowledge is acquired and how individuals construct knowledge to make sense of their world” (Matson J. O. & Parsons, 2006). Inquiry-based instruction, meanwhile, is engagement in learning science that requires coordination of both knowledge and practices simultaneously (Standards & National Research Council, 2012, p. 41). When combining the two, inquiry-based learning allows students to construct their knowledge from experiences and activities (Connelly, He, & Phillion, 2008, p. 73). Seemingly, this philosophical view of learning is a new phenomenon; however, its use has been widespread for several decades.

In the 19\textsuperscript{th} century, American philosopher John Dewey inspired many educators and scholars during this time and beyond based on his child-centered approach to education; he
posited that we learn by doing and from experiences that have meaning to us (Dewey, 2004). In short:

Learning is an activity in which students create meaning. The activity is intensely social and engages the whole being of the child: in this sense, school work and school play are indistinguishable. Dewey suggests that we need to consider standards of a different sort: the broadly human criteria of citizenship ("Democracy and Education 1916, by John Dewey," 2008, p. 1).

Undergirding this philosophical stance is inquiry. In addition to inquiry-based instruction, project-based learning and problem-based learning are other approaches that are noteworthy, particularly, when considering what inquiry looks like in the classroom. Constructivist and inquiry-based approaches allow students to construct their knowledge from experiences and activities that are meaningful; they take responsibility for their learning under the guidance of their teachers.

In Bell’s (2010) research, project-based learning is outlined as an approach to instruction that teaches curriculum concepts through a project (p. 41). “Problem-based learning is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem” (Savery, 2006, p. 12). Another scholar defines problem-based learning as a “method that requires students to be responsible for their own learning and allows them to gain access to knowledge through investigation, inquiry, and criticism” (Inel & Balim, 2010, p. 4). Therefore, in an inquiry-based classroom, some approaches could co-exist; constructivism, however, is the root of inquiry-based learning.
Assessments play a critical role in inquiry-based learning and teaching to determine to what extent a pedagogy is helping students acquire skills and content mastery. In inquiry-based instruction, assessments are ongoing or formative; that is, “continuous assessment of students’ understanding to improve teaching and learning is required” (Araceli Ruiz-Primo & Furtak, 2006, p. 206). During learning, the teacher provides feedback to the student. Assessments can also be summative. This type of assessment includes tests at the end of the study unit (Demırcı, 2009). Both kinds of assessments can help teachers know what they may need to change in their pedagogical approaches to meet goals and objectives (Barell, 2012). There are other indicators to help teachers respond, such as understanding how inquiry looks in the classroom.

Krajcik & Merritt (2012) asserted that the use of inquiry in the classroom can be observed, for example, when students are using science practices where they are “constructing and revising models based on new evidence to predict and explain phenomena and to test solutions to various design problems in the context of learning and using core ideas” (p. 7).

Despite how inquiry looks in the classroom; there are barriers to its successful implementation: “Teachers are unclear about the meaning of inquiry as it relates to pedagogy and assessment, and this confusion causes them to perceive inquiry as being difficult to implement in the classroom” (Wee, Shepardson, Fast, & Harbor, 2007, p. 64). Thus, interfering with classroom management that can prevent inquiry teaching and learning (Geier et al., 2008). Anderson (2002) provided insights about such barriers:

…limited ability to teach constructively, prior commitments (e.g. to a textbook), the challenges of assessment, difficulties of group work, the challenges of new teacher roles, the challenges of new student roles, and inadequate in-service education. The political dimension included limited in-service education (i.e., not sustained for a sufficient
number of years), parental resistance, unresolved conflicts among teachers, lack of resources, and differing judgments about justice and fairness. The cultural dimension—possibly the most important because beliefs and values are so central to it—included the textbook issue again, views of assessment and the “preparation ethic,” i.e., an overriding commitment to “coverage” because of a perceived need to prepare students for the next level of schooling. (p. 8)

On the other hand, even with some barriers, when inquiry-based instruction is implemented, research generally supports that it has been effective in increasing science achievement of all students (Etuk et al., 2011; Ifenthaler, 2011; Kahle, Meece, & Scantlebury, 2000; Liu, Lee, & Linn, 2010; J. Marshall & Alston, 2014). Conversely, a study by Pine et al. (2006) did not produce significant results. In a study with over 1,000 fifth-grade students from 41 school districts, the authors found no significant difference between hands-on, inquiry-based curricula and the textbook approach. In spite of these adverse results, key features of inquiry-based teaching and instruction are highly effective.

**Key Features of Inquiry-Based Teaching and Instruction**

The key features of inquiry-based teaching and instruction that have been shown to be effective in project-based learning and problem-based learning are teacher-student roles, professional development, and time. Scholars have identified key features that increase achievement of science content and practices. It is important to understand that teachers and students have specific roles in inquiry. Savery (2006) describes the teacher’s role as a “facilitator of learning (encouraging/expecting higher-order thinking) and a provider of information” (p. 16); learning is student-centered, hands-on, and based on real world problems (Demirci, 2009; Granger et al., 2012). The student’s role is to engage, explore, explain, evaluate,
and elaborate (Biological Sciences Curriculum Study, 2014). The table below delineates the essential features of inquiry-based learning, project-based learning and problem-based learning.

An interpretation of the table highlights how the different approaches can supplement each other to promote inquiry as well as 21st century skills for a deeper learning of science content that includes science, engineering, and STEM.

Table 2

<table>
<thead>
<tr>
<th>Inquiry Practices</th>
<th>Essentials for Project Based Learning</th>
<th>Problem Based Learning Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions (for science) and defining problems (for engineering)</td>
<td>Significant Content</td>
<td>Real world problems that foster inquiry and embody key concepts like change, equality, and environment</td>
</tr>
<tr>
<td>Developing and using models</td>
<td>A need to know</td>
<td>Choices about content as well as ways to learn and share understanding</td>
</tr>
<tr>
<td>Planning and carrying out investigations</td>
<td>A driving question</td>
<td>Objectives reflecting the highest of intellectual challenges, including the need to pose questions, conduct purposeful research, think critically, make decisions, draw reasoned conclusions with supported evidence</td>
</tr>
<tr>
<td>Analyzing and interpreting data</td>
<td>Student voice and choice</td>
<td>Experiences in small group collaboration</td>
</tr>
<tr>
<td>Using mathematics and computational thinking</td>
<td>21st century skills</td>
<td>Feedback students receive from classmates and teachers</td>
</tr>
<tr>
<td>Constructing explanations (for science) and designing solutions (for engineering)</td>
<td>Inquiry and innovation</td>
<td>Occasions to revise, modify, and elaborate on findings</td>
</tr>
<tr>
<td>Engaging in argument from evidence</td>
<td>Feedback and Revision</td>
<td>Engagement in planning of, monitoring of self-reflection on work, progress, results</td>
</tr>
<tr>
<td>Obtaining, evaluating, and communicating information</td>
<td>A publicly presented product</td>
<td>Opportunities to obtain pre, formative, summative assessment information Clear and easy to follow curricular structure centered on authentic problems and inquiry Teachers and students sharing control of decision making, teaching, and learning</td>
</tr>
</tbody>
</table>


These key features underscore the stance of the NGSS on how inquiry should be conducted to deepen learning of content, practices, and 21st century skills.
NGSS emphasizes “depth over breadth” in teaching integrated content and practices to enable students to master the content. Considering classroom time restraints, the Framework and NGSS focused on a small set of core ideas and crosscutting concepts that are built over time to allow students engaging opportunities to experience scientific inquiry and engineering design (A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012). STEM, however, is a component of NGSS if we take into consideration its three dimensions: science and engineering practices, crosscutting concepts, and core ideas in four disciplinary areas -- physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science (NGSS Lead States, 2013b). Evidence supports these strategies of integrated content and practices to master science content. Granger et al. (2012) found that learning outcomes related to elementary students’ understanding of space science concepts were higher for those enrolled in classrooms engaging in scientific practices through a student-centered approach as opposed to teacher-centered one. A study by (Panasan & Nuangchalerm, 2010) “compared learning achievement, science process skills and analytical thinking of fifth grade students who learned by using organization of project-based and inquiry-based learning activities” (p. 253). The results revealed that teachers using the approach were effective and efficient; and the comparison revealed a statistical significance of 0.05.

A recent study in Hong Kong (Song, 2014) showed that students in Grade 6 advanced their content knowledge in science inquiry using apps on their own mobile devices to follow an inquiry model of science practices. This study was based on the students’ perception of their learning experiences with their own devices. On the 5-point Likert scale, the score was above 4 in all dimensions: content knowledge, metacognitive skills, and social and motivational. By contrast, Kirschner, Sweller, and Clark (2006) presented in their analysis the failure of minimal
guidance in constructivist, problem-based, and inquiry-based teaching, along with other approaches. They argued that minimally guided instruction is less effective than other instructional approaches that place emphasis on strong guidance to support learning. Despite these arguments, if teachers receive professional development for inquiry-based teaching, then students can master content and practices. Thus, professional development is another key feature of inquiry-based instruction and learning.

The NGSS alone will not increase the learning of science content. The framework and NGSS will not lead to improvement in the K-12 science education unless other components of the system change—curriculum, instruction, and professional development (A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012, p. 17).

Marshall and Alston (2014) revealed that “teachers begin to excel when PD is focused on sustained interactions/interventions that help to scaffold teacher practices from prior typically confirmatory activities or lecture to more intentional interactions that challenge students to model concepts, explain and justify thinking, and question ideas and the world around them” (p. 819). Another seminal study also found that, after teachers have been properly trained or professionally developed, they need to allot sufficient time in the practice phases of exploration as well as the in the phase of explanation for students to achieve deeper learning of content (J. C. Marshall & Horton, 2011). Lastly, a professional learning community (PLC) is a good resource through which teachers can receive strong professional development. In a PLC, teachers collaborate to improve student achievement. A study that performed “multifaceted assessments of inquiry-based instruction” compared teachers in an inquiry cohort to those in a typical cohort. Students of teachers who were in the inquiry cohort performed better than those in the typical cohort ($p < 0.01$). Also, colleagues who were at the same school and were teaching the same
units benefited from each other as did their students ($p < 0.05$). These instructors were able to discuss the effectiveness of teaching strategies and to consider the weaknesses and strengths of the pedagogical methods (Liu et al., 2010). Although the authors did not call this a professional teaching community (PLC), the discussion follows the PLC process, which indicates the PD should be ongoing to meet the student needs and to strengthen pedagogy. Moreover, professional development needs to be provided in the areas of instruction and curriculum, and also, as highlighted in the previous section, of assessments.

**Summary**

This review provided an overview of policy documents and of national and global studies to show the significance of inquiry-based learning and 21st century skills for citizenship. Common themes that evolved included standards, skills, practices, and content mastery; also important was an understanding of the roles and expectations of students and teachers for the purpose of student achievement.

Although the NGSS and P21 frameworks have distinct characteristics, they are interconnected to provide a guided approach for advocating the need for 21st century skills. Both are aligned with the Common Core State Standards (CCSS), which is “set of standards that were created to ensure that all students graduate from high school with the skills and knowledge necessary to succeed in college, career, and life, regardless of where they live” (Core Common Standards, 2014) [http://www.corestandards.org/about-the-standards/](http://www.corestandards.org/about-the-standards/). According to the CCSS website, these standards were developed as a result of the recognition of the academic stagnancy of U.S. students when compared to international peers. The NGSS and P21 do not replace these standards even though they have the same endpoints: alignment with the CCSS; career expectations, based on rigorous content and application of knowledge through higher-order
thinking skills; and the quality of being informed by other top performing countries in order to prepare all students for success in our global economy and society (NGSS Lead States, 2013a).

This review has revealed that this study will add to the literature in the following areas: 21st Century skills are needed to prepare all students for college and career readiness; constructivist, inquiry-based instruction increases achievement of all students; key features of inquiry-based teaching and instruction that have been shown to be effective in project based learning and problem-based learning are teacher-student roles, professional development, and time. Specifically, this study will address several gaps in the literature: how inquiry-based science encompasses or promotes 21st century skills for college and career readiness; how a curriculum guided by science standards can undergird inquiry-based instruction, and teacher and student roles in an inquiry-based class where assessments are aligned with the NGSS and the curriculum simultaneously.
Chapter Three: Research Design

Students need to graduate with 21st century skills to be college and career ready and to be competitive in a global marketplace. According to Minner et al. (2010), a positive trend exists favoring inquiry-based instructional practices that purportedly not only increase science content knowledge, but also 21st century skill development. The suburban ATSD implemented an inquiry-based science program based on this assumption; however, the degree to which the program has been meeting students’ needs for science content knowledge and 21st century skills development had not, prior to this study, been explored. Research providing an understanding of the process through which that inquiry-based science program contributes to attainment of science content and 21st century skill development could help to not only improve the delivery of the specific program, but it could also provide a model that other schools might adopt. Constructivist theory was used to deconstruct and understand how a K-8 inquiry-based science program in ATSD prepares students with content knowledge while simultaneously developing essential skills for college and career readiness to promote 21st century citizenship.

The purpose of this descriptive case study was to engage with multiple stakeholders of ATSD to formatively assess the successes and obstacles for helping students to achieve science content and 21st century skills through the inquiry-based curriculum. To understand the process, implementation, and outcomes of the program fully, the participants included central district administrators, school administrators, and teachers. This chapter delineates the methods that were employed to best answer the research questions from multiple perspectives.

Research Paradigm

This study falls within the epistemological constructivist–interpretivist paradigm; it is based on the assumption that, through intense interaction and dialogue, both the participants and
researcher reached deeper insights (hermeneutical discovery) into the *Erlebnis* (lived experience) (Ponterotto, 2005). This lived experience, as it pertains to this study, included how the participants perceived the design, implementation, and the process of the science inquiry-based program and its promotion of 21st century skills. Findings from this lived experience were co-constructed as a result of interaction and dialogue between the researcher and participants, thus underlining that a qualitative approach is the best research design (Ponterotto, 2005).

**Research Design**

A qualitative approach was the research design that best aligns with this paradigm. Creswell (2009) noted that a qualitative approach allows the researcher, who is the key instrument in qualitative research, to gather data from multiple sources within the natural setting in order to gain a holistic account into a phenomenon. These sources include: collecting data from documents, interviews, and archival records (Creswell, 2009). The researcher was interested in understanding this phenomenon by analyzing the meanings the participants derived from their interactions within context, thus undergirding the primary goal of a qualitative study—to uncover and interpret meanings (Merriam, 2002). This “basic interpretive qualitative research” was framed using the theoretical lens of constructivism in order to answer the following research questions:
Research Questions

This study sought to answer the following research questions. How does the implementation of an inquiry-based program within the ATSD support the acquisition of science content knowledge and the development of 21st century skills?

a. What was the rationale for the program?

b. How well did the program meet its desired goals?

c. What was the transition process like?

Moreover, the underlining principle of an inductive, emergent approach is that by gathering information from varied data sources, themes and concepts can be built to strengthen the argument and understand a phenomenon from multiple perspectives (Creswell, 2009; Merriam, 2002).

Research Tradition

The research used a case study aligned with the tradition outlined by Yin (2009). Specifically, it was a descriptive case study because the focus was not only on the process, but also on the outcome. Furthermore, by using the theoretical lens of constructivism, the researcher provided descriptions with meaning (Meyer, 2001). According to Yin (2009), a case study is the preferred method when (a) “how” or “why” questions are posed; (b) the investigator has little control over the events; and (c) the focus is on a contemporary phenomenon within a real-life context (p. 2). Case study methods cover the logic of design, data collection techniques, and specific approaches to data analysis (Yin, 2009, p. 18). Paradoxically, Stake (1994) a research scholar of qualitative methods, believes that a case study is not a methodological choice, but a choice of an object to be studied. If one chooses a particular case to study, then the case study is defined by an interest in that individual case and not by methods of inquiry (p. 236).
Furthermore, Stake argues that a single case is poor grounds for advancing generalization and that it does not represent the world. It only represents the particular case (p. 245); however, much can be learned from a single case (Merriam, 2002). A case study can provide in-depth descriptions from multiple sources of data that can also include quantitative evidence to provide rigor and trustworthiness. After considering several options, Yin’s approach to case study was chosen for this study, which was largely descriptive in nature.

A single case is justifiable if it is a representative case. That is to say, lessons learned from the case can be informative to others (Yin, 2009). The researcher believes that this study can appeal to its intended audience locally, nationally, as well as globally by understanding the lessons learned about the challenges and successes of the inquiry-based program. Consequently, the stylistic option is descriptive to provide an in-depth picture of the case (Creswell, 2007) in real-life context (Creswell, 2007).

An important feature of a case study is that it must be “bounded in space and time”. ATSD is a good case for understanding this problem of practice because an effort was made to teach science content and 21st century skills through an inquiry-based program. Therefore, this study was bounded in space ATSD and time (program inception to June 2015). Furthermore, it is a suburban school district with a diverse student population, which means it can provide important lessons for similar districts. The focus of the study is on Grades K-8 and takes place within two elementary and one middle school. These three schools are the units of analysis.

The demographics of this specific case are diverse: ethnicity, disability as it relates to special educational needs, gender, English language learners, and social economic status (SES). SES is defined by the indicator of students receiving free and/or reduced lunch. In real life
context, this diversity responds to the methodological intent to understand how the program prepares all students with content knowledge and 21st century citizenship.

In sum, research tradition chosen involves a holistic perspective that incorporates multiple stakeholders, which allows the collection of data from many sources to understand the phenomenon from the inception of the program to June 2015.

**Recruitment and Access**

Before collecting data, the researcher had to follow the district’s policy on conducting research within the schools (Appendix A). With full understanding of policy, the researcher sent a letter (Appendix B) to the superintendent seeking permission to conduct research in accordance with policy. Once approval was granted, the superintendent informed all administrators of the research and information about the investigator via email and during their leadership meeting. Henceforth, the research site, archival records, documents, and participants became accessible to the investigator.

This clearance allowed the researcher to send letters, by email, to all stakeholders (Appendices D-G) and, for this specific purpose, it also permitted access to school documents and archival records. All participants who responded were accepted. A follow-up email was sent asking them to schedule a time and place that was convenient for them to be interviewed.

Recruitment was a little difficult, particularly because it was the end of the school year when many teachers were finalizing grades, packing, and completing the last minute items on the administrative checklist. The teacher participants chose the locations and times; they willingly gave up lunch time and personal time after school time to take part in the study. Likewise, building administrators were busy, even so, a couple of them scheduled interviews after the school year ended.


Sampling of Participants

Within this setting, purposeful sampling was used for the target population. In qualitative research, purposeful sampling is used when sites and individuals selected by the researcher can purposefully inform an understanding of the research problem and central phenomenon in a study (Creswell, 2007). The sampling strategy allowed for maximum variation with respect to the aforementioned demographics. As noted by Creswell, the rationale for this sampling strategy was that it documents diverse variations and identifies to capture important patterns from multiple perspectives as well as multiple sources. In a strong plan for a qualitative study, a researcher should include sampling at one or more levels, such as site level, event or process level, and participant level (Creswell, 2007). The plan for this study includes sampling of participants at different sites (the district administration and the school) and from different roles (district administrators, school leaders, and teachers). It also includes process level analysis.

Participants

The sampling of participants was comprised of 11 participants: one central administrator; three school administrators; and seven teachers (See Table 3).

Central administrator. From central administration, the former superintendent was the participant. The former superintendent was chosen because he first proposed and began the transition from the traditional approach to teaching science to the inquiry-based curriculum. These stakeholders were selected to provide insight into the decision-making behind the change and to gain insight of any proposed changes. The former superintendent was also able to describe the goals of the district as a rationale for the change.

School administrators. Each school has three administrators: one principal and two vice principals. The principal of each school has been in his or her position since the program’s
inception and the vice principals have been in their positions since the intended emphasis on 21st century skills became the focus of lesson planning. Oftentimes, the same results of a new curriculum or policy change do not extend to other schools within the same district (National Research Council, 2000). As a result, one administrator from each school was selected as a participant to understand the program and processes at the different schools, school levels, and times.

**Teachers.** There are 75 teachers of science in Grades K-8 in the ATSD. From this population, seven teachers responded and were selected. Although all received a recruitment letter, most did not respond by indicating “yes” or “no” in the subject line of the email. Six responded positively to the recruitment letter. One participant volunteered to be interviewed immediately following an interview with a fellow teacher while the researcher was onsite (see recruitment in subsequent section). Only one teacher responded and was chosen from the K-2 grades at the elementary school. Because many of the elementary teachers had taught multiple grades, this number was sufficient. Three teachers volunteered from Grades 3-5 at the elementary school, as did three teachers from the middle school -- a special education teacher and two regular education teachers. This sample size sufficed because it was a blend of teachers that was representative to yield the best data on the study’s topical issues, particularly lesson plans, inquiry-based instruction, professional development, and activities that reflect the preparation of all students for 21st citizenship. In other words, various perspectives maximized the study and also provided a better understanding of the process into this phenomenon.

Through purposeful sampling, the inclusion of the selected participants allowed for the development of themes for rich details, and the information initiated access to corroboratory or contradictory sources of evidence (Yin, 2009, p. 107), thus positively impacting external validity.
(see discussion on validity in the final section of this chapter). It is important to note that the researcher had to follow the guiding principles of the district for this recruitment.

Table 3

**Demographics of Participants**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Years Teaching Inquiry</th>
<th>Professional Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Simon</td>
<td>Former Superintendent</td>
<td>N/A</td>
<td>9 tenured years in this district and one year in present position</td>
</tr>
<tr>
<td>Jared</td>
<td>Middle School Vice Principal (VP)</td>
<td>N/A</td>
<td>3rd year as vice principal; math teacher prior to becoming VP</td>
</tr>
<tr>
<td>Dr. Esther</td>
<td>Elementary Principal</td>
<td>N/A</td>
<td>10th year as Principal; 2 years a VP; 12 years in this district</td>
</tr>
<tr>
<td>Mary</td>
<td>Elementary Vice Principal (VP)</td>
<td>6</td>
<td>3rd grade teacher in this district for 6 years</td>
</tr>
<tr>
<td>Hannah</td>
<td>2nd grade teacher</td>
<td></td>
<td>Head science teacher; Kindergarten teacher; 15 years in district</td>
</tr>
<tr>
<td>Eva</td>
<td>3rd Grade teacher</td>
<td>9</td>
<td>1st grade teacher for 15 years; 21 years in district</td>
</tr>
<tr>
<td>Lois</td>
<td>5th grade teacher</td>
<td>12</td>
<td>9 years in this district</td>
</tr>
<tr>
<td>Vashti</td>
<td>5th grade inclusion teacher</td>
<td>7 or 8</td>
<td>12 years in district</td>
</tr>
<tr>
<td>Sarai</td>
<td>8th grade science teacher</td>
<td>9</td>
<td>Science cluster chair for middle school; all 9 years in this district</td>
</tr>
<tr>
<td>Ruth</td>
<td>8th grade science teacher</td>
<td>7</td>
<td>7 years in this district; 13 years of teaching science including biology and chemistry</td>
</tr>
<tr>
<td>Phebe</td>
<td>Special education middle school science teacher</td>
<td>9</td>
<td>Pull out resource and inclusion science teacher; 10 years in this district</td>
</tr>
</tbody>
</table>
Protection of Human Subjects

Over these years, I earned the respect of colleagues and administrators as being ethical and professional. I approached each teacher and administrator in this manner. Each participant was informed that pseudonyms were to be used for them; the identity of the research site was also protected to maintain anonymity. The researcher reiterated that participation in the study is invaluable; however, each participant was also made aware of the fact that they could withdraw from the study at any time. The purpose of the interviews was shared; participants were told the purpose of these was to collect data to be used as evidence to formatively evaluate the process and implementation of the inquiry-based program and 21st century learning. All participants were given an informed consent form to read (Appendix H). Afterwards, the researcher asked all participants if they had any questions before they signed the consent form to take part in the study. All participants received a copy of the signed consent form.

Further, the demographics of ATSD students were analyzed using sources that the public may easily access (more details in data collection section). The identity of all students was protected.

Lastly and most importantly, IRB approval (see Appendix C) was granted to ensure that all human subjects that participated in the study have been protected.

Data Collection

Prior to collecting data, Yin (2009) suggests that a logic model may prove an effective technique for pattern matching because it lays the groundwork for a high quality study (p. 162). The logic model for this study was a program level model that was referred to during data collection. The logic model helped the researcher use the literature and data collected to understand the process for achieving the desired outcome. In qualitative research, data collection
and data analysis occur simultaneously (Merriam, 2002). Eventually, the same model was used for data analysis, as discussed in the data analysis section of the subsequent chapter.

According to the case study tradition, six forms of data collection are recommended: documents, archival records, interviews, direct observation, participant observation, and physical artifacts. However, in order to answer the research questions for this particular study, the researcher used only documents, interviews, and archival records.

**Documents**

Documents were used to corroborate and augment evidence from other sources (Yin, 2009). The researcher gathered information from email correspondence, Google Documents, and faculty meeting agendas on collaboration between stakeholders regarding 21st century skills planning and professional development. Textbooks, examples of student work, and school records were used for insight on how 21st century skills and inquiry-based lessons were implemented to demonstrate relation to real-life context. The researcher took caution to ensure that documents collected were central to the inquiry (Yin, 2009). These documents were easily attainable due to cooperation by teachers and administrators.

**Interviews**

Interviews are one of the most important sources of case study information because, unlike surveys, they tend to be fluid and not rigid, open-ended and conversational (Yin, 2009). This study included a technique often used by researchers working in an interpretive paradigm -- the in-depth or semi-structured interview. Questions were asked of key respondents about the facts of a matter as well as their opinions about events; interviewees were asked to propose their insights into occurrences. The interviewees’ propositions were used as a basis for further inquiry (Yin, 2009, p. 107). Some interviewees suggested other sources of evidence and led the
researcher to include other people in the research process. The interviews lasted between 16 and 60 minutes at locations chosen by the participants. Stake (1995) recommends that the researcher ask that participants examine rough drafts of writing in which their words are featured (as cited in Creswell, 1998, p. 213; Merriam, 2002). Considering this recommendation, which is known as member checks, all transcripts were emailed to the participants for their review. Most participants received their transcript the day following the interview; however, there were three participants who received their transcripts within four days. Member checking is also a strategy to ensure validity as discussed in the final section of this chapter.

In-depth interviews took place over several sittings and interview protocols (Appendix J) were continuously developed in response to participants’ behaviors, emerging patterns, and themes. The researcher was allowed flexibility to select topics and to probe more deeply as necessary; she explored issues without formalizing a specific order or wording of questions ahead of time (Merriam, 2002, p. 13). This interview type paralleled the interview guide approach. The interview guide approach is defined as flexible, sensitive, and situational; it includes open-ended responses (Patton, 1990, pp. 283-284).

This approach was applied by the researcher, and the guidelines of McNamara (2009) were followed for interview preparation, types of topics in questions, wording of questions, conducting interviews, and all protocols suggested immediately after the interview.

As previously noted, all participants chose the locations and times for the interviews. All interviews were conducted at the research site in teacher classrooms and in the offices of the administrators, with the exception of the former superintendent, Dr. Simon, and one teacher, Hannah. Dr. Simon invited me to interview him at his office in his new district. Hannah was too busy at the end of the school year to be interviewed and agreed to drive one and one-half hours
the following week in order to participate. Her preference was to be interviewed at the home of the researcher over choices that included her home, Starbucks, and the investigator meeting her half-way at a different location. The interview took place four days after the school year ended.

All interviews were audiotaped and transcribed for “more accurate rendition” (Yin, 2009, p. 109) using the Rev iPhone App. In addition to being more accurate, Rev was chosen because of its security and fast turnaround time, usually within 24 hours. However, one transcript took two days. As backup, the researcher used a handheld digital voice recorder, Olympus WS 821. All transcripts were reviewed and edited for accuracy by the researcher, and depending on the transcriber, the researcher may have had to make more corrections when compared to others, which took more time. Afterwards, the transcripts were forwarded to the participants for their reviews. The transcribers were specifically asked to inform the investigator of any needed corrections.

On the other hand, before being audiotaped, all participants were informed that they would be recorded. If they refused, then the interview would not take place (Yin, 2009). Mary, the administrator, expressed some apprehension, but when she read the consent form on the storage of the data, she stated that she felt comfortable to be interviewed once she understood that component.

**Archival Records**

The state website, which has the School Report card of every public school, was used along with records from the district to collect information regarding school demographics. All records were easily accessible and were used to analyze the outcomes of the program.

In sum, the use of multiple sources for establishing findings or conclusions in case studies increases trustworthiness. Yin (2009) refers to this principle for data collection as
triangulation, which is one of the three principles he noted that maximizes the effectiveness of case studies. The other two are creating a database and maintaining a chain of evidence. These are discussed in the next section.

**Data Storage**

A case study database markedly increases the reliability of the entire case study (Yin, 2009, p. 119). For this reason, a database was created using OneDrive Cloud. This created an external drive where all tapes, case study notes, documents, and transcripts were stored using pseudonyms. All data was organized, categorized, completed, and available for ready retrieval of the information as needed according to case study protocol. The paper documents were shredded after they were electronically scanned and saved into the respective locations; photos were deleted from the cell phone camera after being downloaded into the proper folder; and the pseudonym key was stored in a separate electronic file.

Analytic memos were organized according to sources of information for later retrieval in Dedoose online analytical software and downloaded into the computer. These drives were maintained to be used as a chain of evidence accessible by the researcher and any external observer (Yin, pp. 120-122).

By maintaining a chain of evidence, the reliability of the case study was increased. According to Yin (2009), this chain allowed the external observer—the reader of the case study—to trace the steps in either direction (from the conclusion to the research questions or from the research questions to the conclusion). The external observer is able to move from one part of the case to another with clear cross referencing to methodological procedures and to the resulting evidence (p. 124).
Data Analysis

In case study research, data analysis consists of making a detailed description of the case and its context (Creswell, 1998; Merriam, 2002). For preparation of analysis, several analytic strategies have been identified by qualitative authors as approaches to organizing and searching the voluminous data that are generated in a qualitative study (Creswell, 1998). However, for this study, Creswell’s (1998) three steps for analysis were applied. The researcher: (a) transcribed interviews, scanned documents, and sorted data into the sources of information; (b) read through all the data in order to reflect on what the participants were saying and what data were needed and the credibility of the data collected; and (c) began analysis with coding to develop themes for reduction and interpretation of data.

The subsequent sections of this chapter delineate the following: coding; the appropriateness of evaluation coding as the method chosen for this study; and content analysis that was used to make sense of the data.

Coding

A code is a keyword or phrase that symbolically assigns a summative, salient attribute to textual or visual data (Saldaña, 2009, p. 3), whereas, coding is the transitional process between initial and more extensive analysis (p. 4). The latter is a heuristic or exploratory problem solving technique without specific formulas to follow. According to Saldaña (2009), the terms code and category are sometimes used interchangeably; however, the terms have distinct significances. When codes are clustered according to similarities and regularities, patterns form and categories develop, thus establishing a link or a connection of analysis (p. 8). For this purpose, Dedoose computer online software was identified and used by the investigator to assist with the coding, categorizing or counting key words, as well as to ease retrieval of the collected data from the
multiple sources. This qualitative and mixed method research web application wove text and memos for analysis. Also, the Dedoose application provided visualization data, such as tables, charts, and graphs for coding the data to represent it as a “window to deeper aspects of the qualitative data”.

**Analytic Memos**

Saldaña (2009) posits that coding and analytic memo writing are concurrent analytic processes; therefore, analytic memos were used to help make sense of the data. Analytic memos are written thoughts of anything that comes to mind of the researcher about the coding or analysis of data that is significant. This can include unanswered questions, frustrations with analysis, insightful connections or anything that the researcher deems as acceptable content to reflect on (Saldaña, 2009 p. 33). Dedoose was also used to date and link memos to a source or code for use in the analysis. Coding was completed in cycles using the various “manually driven” descriptors and filters of the program to search for themes and patterns that would answer the research questions. Because Evaluation Coding encompasses In Vivo, it was used in the first cycle and patterns were employed after this first cycle, which Saldaña (2009) refers to as an “amalgam” of coding.

**Evaluation Coding**

Considering that the purpose of this study was to formatively evaluate the inquiry-based program in ATSD and to outline how it prepares students for 21st century citizenship, evaluation coding was deemed appropriate. Patton (2002) defines program evaluation as "the systematic collection of information about the activities, characteristics, and outcomes of programs to make judgments about the program, improve program effectiveness, and/or inform decisions about future programming. Policies, organizations, and personnel can also be evaluated" (p. 10).
Through a holistic approach, themes and patterns emerged regarding the implementation, process, and outcome of the inquiry-based science program. Thus, the study employed evaluation coding and an amalgam of in vivo coding (which notes specific qualitative evaluative comments) as well as descriptive coding (to note the topic). All codes related to personnel and programs since evaluation coding should reflect the nature and content of the inquiry (Saldaña, 2009, p. 98). Data were reduced to piece together an analysis of this phenomenon.

**Content Analysis**

Inductive analysis encompasses the development of patterns, themes, and categories (Patton, 2002). Themes and patterns are the outcome of coding (Saldaña, 2009). In this study, documents were closely examined to establish recurring words or themes. Having searched the text in this manner, voluminous qualitative data were reduced in a sense-making effort in order to find core consistencies and meanings that is referred to as content analysis (Patton, 2002). The core meanings are called patterns and themes, and this search process is theme analysis or pattern analysis.

**Theme Analysis Versus Pattern Analysis**

Patton (2002) explicated very little distinction between the theme and pattern: a theme is a topic or category and a pattern is a descriptive finding. As a result, both will be used in this study. Saldaña (2009) observed:

Theme analysis is a strategic choice that would allow the researcher to use the primary questions, goals, frameworks, and literature review to search for themes. Through the employment of carefully planned questions and techniques, participants construct meaning of what the researcher is trying to explore. Furthermore, “meaning
interpretation” of themes during the first cycle of analysis can explain the “why” and “what” of the topic. (p. 140)

Using a multifaceted approach to analysis — coding, writing memos, logic models, and theme analysis — allowed categories to become more defined for reflection on emergent patterns and meaning of the participants’ experiences into this phenomenon (Saldaña, 2009). In general, the practice of analyzing the data is a cycle, moving between theory and data, with each modifying the other. It is continuous, and sources should be coded using codes relevant to the frameworks, latent content and their manifest (cited by Merriam, 2002, p. 273). Thus, ultimately qualitative research can lead to naturalistic generalization, an aim that would allow others to learn from this case or to apply it to a population of other cases (Creswell, 1998).

**Trustworthiness**

Trustworthiness of a research study is important in evaluating its worth (Lincoln & Guba, 1985). Several principles were followed in this study to minimize threats to validity. In addition to maintaining a chain of evidence, which increases reliability, or consistency of findings, credibility and transferability are significant to establishing validity. First, credibility was established using triangulation and member checks as evaluation techniques.

Triangulation is the most used and well-known strategy to employ to establish trustworthiness (Merriam, 2002; Yin, 2009). This principle uses multiple sources of evidence (Yin, 2009). “With data triangulation, the potential threat of construct validity can be addressed because the multiple sources of evidence essentially provide the multiple measures of the same phenomenon” (Yin, 2009, pp. 116-117). Triangulation, a major strength of case study data, allows for “converging lines of inquiry- a corroboratory mode” (pp. 115-116).
Member checks were used as noted in the data analysis section. Although controversial in qualitative research, (Cohen & Crabtree, 2006), Lincoln and Gupa (1985) posit that member checks are the most crucial component in establishing credibility. Using this strategy, participants were asked to review transcripts of interviews; they were invited to comment on the researcher’s documented interpretations after the initial analysis (Merriam, 2002).

Second, in qualitative research, the researcher is the primary instrument for data collection and analysis of the participants’ interpretation or understandings of the phenomenon. These rich descriptions, resulting from well described details of the conclusions, can bring applicability of findings to other contexts. This technique is termed transferability and can increase external validity (Lincoln & Guba, 1985).

Most importantly, the researcher committed to making the entire process as explicit as possible so that the final results of the data collected reflect a concern for construct validity and reliability; this study, therefore, may be challenged by further analysis (Yin, 2009, p. 124).
Chapter Four: Report of Research Findings

The purpose of this descriptive case study was to engage with multiple stakeholders to formatively assess the process of implementing an inquiry-based, K-8 curriculum designed to help students learn science content and 21st century skills. In order to evaluate this phenomenon, this chapter presents: (a) the research context and participants; (b) a description of the program logic model; (c) the rationale for change, along with the goals of the program; (d) the implementation process; and (e) a summary of successes and shortcomings.

Research Context

Areal Township School District (ATSD) has approximately 2,800 students in grades K-8 and is situated in a suburban east coast state. These grades are housed in three different schools: a K-2 school, a school for grades 3-5, and a middle school for grades 6-8. For the sake of simplicity, pseudonyms for the schools are School K-2, School 3-5, and Middle School 6-8. School K-2 also has a Pre-K grade level, but that was not part of the focus of the study.

Demographics

According to the website of the State Department of Education, the student population in ATSD is diverse. The approximate ethnic make-up is 48% White, 32% Black, 9% Asian, 9% Hispanic, and 2% American Indian, Pacific Islander, or Two or More Races. Approximately 27% of this population is economically disadvantaged, 16% of the students are classified as having a disability, and 2% are considered to have limited English proficiency, which means that English is not their first language (Specific citation omitted to preserve ATSD anonymity). Although controversial, English Language Learners (ELL) is the most used name to classify this population of students (Garcia, Kleifgen, & Falchi, 2008).
School Leadership

Each school has a principal and two vice principals. Approximately 75 teachers, or less, currently teach science in each school. Recently, School K-2 underwent a major change by adding a head science teacher position. The other schools already had this position in place. The teachers holding that position are called the science cluster chairs, and as such is the go-to-person for the other science teachers as well as the administrators. The cluster chair facilitates meetings with science teachers and provides support such as seeking and facilitating professional development, sharing lessons and teaching strategies, acting as a liaison between teachers and administrators, and ordering science supplies. Collectively, the team of cluster chairs meets monthly with central administrators, building administrators, and other school leaders on subject and school related educational issues.

Participants

Background information about the participants is provided here to enable a better understanding of their perceptions on the transition and how the inquiry-based program is helping students in Grades K-8 learn science content and 21st century skills. This information is particularly useful for understanding how the program evolved from rationale to outcome over ten years from the perspectives of all participants, veteran and new. All participants are identified with pseudonyms.

Elementary school grades K-2. Two participants were interviewed from School K-2: Esther and Hannah.

Esther. Esther has been the principal of School K-2 for 10 years and, prior to this promotion, she was vice-principal at School 3-5 for two years. She was excited to be interviewed
and spoke with enthusiasm and optimism about the science transitioning process and the
direction her school is taking.

**Hannah.** Hannah was the only teacher participant to volunteer from School K-2. She is a
second-grade teacher, and she is also the head science teacher. She has been teaching in ATSD
for 15 years. During those years, she taught kindergarten as well as first grade.

Science is of great interest to Hannah. She stated that when she taught kindergarten,
there was no science curriculum, so she “researched and borrowed some from companies so her
classroom always had it.” This statement alerted the researcher to question and search the
evidence collected to corroborate this statement and determine in which grade the inquiry-based
program actually began.

**Elementary school grades 3-5.** Four participants were interviewed from School 3-5:
Mary, Eva, Lois, and Vashti.

**Mary.** Mary is the vice-principal of School 3-5 and the supervisor of science — positions
that she has held for the last three years. Prior to holding these titles, she was a third-grade
teacher at this school. Mary had experience with both the inquiry-based program and the
traditional approach to teaching science in ATSD. Mary spoke about the science lab as a place
where the “hands-on stuff happened” before transitioning to the inquiry-based science. She was
able to give an account of what happened before, during, and after the transitioning; this
provided valuable insights and data to the researcher, given her perspectives as both a teacher
and an administrator.

**Eva.** Eva is a third-grade teacher. She taught 20 years in ATSD. Before teaching third
grade, she was a first-grade teacher for 15 years. She described her transition from teaching first
grade to third grade as a “big jump with more student accountability.” Her classroom was
decorated with posters and charts. However, no student science work was displayed due to the teaching schedule in School 3-5. Although her interview was at the end of the school day, Eva was energetic. She spoke with humor about her past “broken-up” schedule due to lunch and related arts that she referred to as specials. When it is time for specials, she had to “place a bookmark” in her lessons. She stated that she would tell the students, "Okay, hold that thought, we're coming right back!" It was obvious that she has a passion for teaching and making it fun.

**Vashti.** Vashti has been in ATSD all of her 12 years of teaching. She was a fourth-grade teacher for eight years before becoming a fifth-grade teacher. Her class is called an in-class resource (ICR) class. This setting has a mix of students: regular education pupils and students with special learning needs who have individual education plans (IEPs). These plans are designed by law to ensure that individual educational needs are met. There is a special education teacher, a teacher’s aide, and a regular education teacher in this class. Because it was the end of the school year, very few posters remained on the wall and no science work was evident, again due to the teaching schedule. This schedule displeases Vashti. She stated, “In my opinion, science should be taught all year.”

**Lois.** Lois is a fifth-grade teacher with 12 years of experience teaching inquiry-based science. She has advanced degrees in teaching and educational leadership. Before coming to ATSD, Lois taught inquiry-based science as a second-grade teacher for three years. She spoke regretfully about going from teaching science all year to teaching science half the year: “Science is what I enjoy the most.”

**Middle school grades 6-8.** Four participants were interviewed from Middle School 6-8: Jared, Sarai, Ruth, and Phebe.
**Jared.** Jared is the vice principal of Middle School Grades 6-8. This is his fourth year in the position. Along with being the vice principal, he is also the science supervisor. Jared was a math teacher at this school prior to becoming an administrator. Although Jared taught math, he was seemingly knowledgeable regarding the current and future needs of the inquiry-based program.

**Sarai.** Sarai is an eighth-grade science teacher and a science cluster chair. She has taught in ATSD for nine years, arriving one year after the transition to the inquiry-based program. Sarai teaches three ICR classes and one anatomy class. The anatomy class has a “curriculum driven for enriched students;” however, there are students in this class with IEPs and other special needs as identified by Section 504 of the Rehabilitation Act. This specific section of the Rehabilitation Act, a federal civil rights law, protects students with disabilities from discrimination.

The classroom environment, which is a science lab, was decorated with posters and student work. Two students can sit at one lab table, and the tables were arranged in four rows, with six tables in a row. In addition to the teacher’s desk in front of the class, there was a science demonstration table with a drop down mirror above it, which provided a close visual for students seated in the back of the class.

**Ruth.** Ruth is an eighth-grade teacher. She has been teaching in ATSD for seven years. She has experience teaching high school biology and chemistry. In her lab, the desks are arranged in rows as in Sarai’s class. They share a lab preparation area that adjoins both classes. Her room was decorated with posters, and student projects were on the lab benches.

**Phebe.** Phebe is a special education science teacher. She is an ICR support teacher in two classes and a resource room teacher with two classes. In the resource room, she has a teacher’s aide. A resource room is where students with IEPs get access to the curriculum, but at
a much slower pace and with any modifications directed by their IEPs. The class size is small, with no more than 10 students, compared to regular education classes which have an average class size of 22. Phebe has been teaching in ATSD for about 10 years. Because she is a special education teacher, she has co-taught with many different teachers. As a result, Phebe provided considerable insight into the curriculum.

**Central administration.** Dr. Simon is the only participant from central administration.

**Dr. Simon.** Dr. Simon, the former superintendent, provided great insight into why the transition to inquiry-based science was made. He was the superintendent of ATSD from 2005 to 2014, and thus was the change agent for this program and many other matters. Even though Dr. Simon is the former superintendent, he is still deeply rooted to the Township because not only is he a resident, he also has three children who currently attend the Township schools, with another having graduated last year.

Before Dr. Simon’s tenure began in the ATSD, he was assistant superintendent in Farewell Township School District (pseudonym) in a different county in the state. Dr. Simon was also part of a national movement at the National Science Research Center, whose goal was to help with science reform by travelling nationally to show teams of teachers and administrators how to implement inquiry-based science into their schools.

**Program Logic Model**

A program logic model was used to evaluate this phenomenon; its purpose was twofold. First, a logic model delineates a series of events over a broad range of time in stages of repetitive cause-and-effect patterns (Yin, 2009). Second, a logic model not only lays the groundwork for a high quality study (p. 162), it also helps to match empirically observed events to theoretically predicted events (p. 149). The program logic model in Figure 4.1 consists of key components to
report findings on why the change was made (rationale), what were the desired goals, and what was the transition like (process) in order to gain a deeper understanding of how implementing an inquiry-based science program contributed to learning science content and 21st century skills.

Figure 4.1 Program Logic Model. This figure illustrates the Implementation of Inquiry-based Science in ATSD.

**Rationale for the Inquiry-Based Program**

The primary rationale for implementing the inquiry-based program at ATSD was to align the science curriculum with national science educational standards. The old approach did not include best practices on how students learn science: it was “textbook driven and knowledge driven, and did not align with the current science reform efforts” (Dr. Simon). Dr. Simon described the state of the science program as it was when he became ATSD superintendent:

There didn't seem to be a rhyme or reason to the topics that were covered. The science curriculum was very activity or project-based. It was kids doing activities about science, like making posters, like coloring, like engaging in various group work or writing projects, but they weren't doing science. They weren't doing inquiry. They weren't
wondering about some phenomenon and then developing an experiment and trying some things out, and developing a hypothesis, and drawing conclusions out of that experience. Therefore, “guided by the philosophy that students shouldn't be learning about science, students should be doing science, the program was revamped from K-8 to reflect the National Science Foundation and National Science Research Center's promotion of inquiry-based science reform” (Dr. Simon). The next section presents the program goals, as well as examples of each goal.

**Desired Program Goals**

ATSD had two program goals to attain: meaningful learning to increase student engagement and using inquiry-based practices to increase science content knowledge and develop 21st century skills.

**Meaningful learning**

Meaningful learning encompasses “practices in which learners are engaged in building, refining, and applying scientific knowledge to understand the world, and not as rote procedures or a ritualized ‘scientific method’” *(A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012, p. 254).*

**Outdoor experiences.** Hannah’s students planted a wildflower garden in the courtyard of School K-2 (See Appendix K Courtyard). From April to June, the students visited the garden to measure the growth of the seedlings. The students were responsible for recording these measurements in their science journals (see Appendix K). Three days after the students planted the wildflowers, Hannah began the “Plant Unit.” These lessons were parallel. In the classroom, the students planted snow peas, made predictions, and recorded observations such as height measurements. Therefore, planting wildflowers was an engagement lesson. In addition to Hannah, other teachers were “actually taking students out on the courtyard. They're developing
lessons with live insects, which is different from what we used to do; it used to be only just a textbook” (Esther).

**Projects.** Many teachers assigned projects that were purposely “linked to what they’ve learned” (Mary). Teachers required their students to either work alone or in a group. Lois’ students did “independent projects this year on living systems, where they investigated a disease or disorder on one of the digestive, respiratory, excretory or circulatory systems” (See Appendix L). Lois also stated that some students performed skits.

Findings revealed that ATSD teachers gave students many project options that applied scientific knowledge, such as those given to students in grade 8. Sarai and Ruth’s students worked in groups to create books, game boards, models, displays, videos, or skits (Appendix P). Further, the students presented their projects to the class. The rubric showed “presentation” as a component graded along with the final project (See Appendix O). Projects were not only meaningful learning, but were also assessments.

**Learning centers.** Learning centers are a collection of materials and activities designed to teach, reinforce, or extend students' knowledge, understanding, and skills (Cox, 2008). Such centers were observed in two of the classrooms. These centers were structured to relate to students’ experiences.

Hannah’s class had a science center that included a hanging vocabulary list, science tools, plants, seed starters, soil, magnifying glass, watering can, books, and containers (See Appendix K). She referred to these centers as “ongoing” for students to further explore the concept they were learning as an activity after they have finished classwork. “Rather than the students coming in on the first day of school with a well-decorated room,” Hannah allowed them to create their own learning environment because she finds that “they use it more.”
Ruth was forthright with her stance on literacy: “there has to be balance in middle school on content and inquiry-based. They should be able to learn not only by doing, but also, by this age, to read something and get that idea and articulate it as well.” In the adjoining class was a literacy center. It had science books and magazines that were neatly organized and accessible to all students to read at their leisure or use for research (See Appendix M).

Groups. In all classrooms, the layout for seating optimized social interaction, collaboration, and communication. The researcher observed that desks were arranged in groups of two or four; a couple of teachers said that groups of five were also ideal. Students had roles that rotated among the group members: a starter, reporter, two people who get the materials, and the clean-up person (Eva). Heterogeneous grouping is used in all classroom settings. Groups are highly favored by the teachers because “students are “pushing one another, challenging one another, assisting one another in that setting” (Jared). Phebe offered her perceptions on group dynamics:

It's funny because when you look at the groups, there's usually a leader, and there may be one or two who want to be a leader. 80-90% I would say, are engaged. You always have the one who's floating off to the side, or just standing that you kind of have to nudge a little, but I think them seeing it in real life, besides just reading about or someone reading it to them, makes a big difference to them. (Phebe)

Vashti described her students’ social interactions during inquiry:

My classroom is an ICR [in-class resource] classroom, so I have a mix of Special Ed [education] and Regular Ed [education] kids for science, we go into groups. I like to make my science groups about four to five kids max in each science group. The social interaction with the kids, and the hands-on, where they can actually socialize and talk
about what's going on and what they see, they have to basically problem-solve. If one wants to do it one way and the other one wants to do it another way, they have to come up with a solution by themselves, rather than me guiding them all the time. Kids love science; they love doing the labs. (Vashti)

Eva shared her thoughts about how the chosen science curriculum promotes this interaction:

I think the program is set up well where you kind of pose a problem or a situation and they have to use the trial and error to try to come to some kind of ... I do like that. I think the program is geared to that. I think they like the fact that they're in charge, less structured—making sure they're doing what they're really supposed to is, another thing, but ... That's all the learning process.

Lois added, “I think that they do perform better when they do it themselves and they reach conclusions on their own.”

Science content and skills development using inquiry-based practices. Along with instruction that was meaningful, the second goal was to have a program that promoted the acquisition of science content knowledge and the development of 21st century skills, using inquiry-based practices. Findings related to this goal included: structured-sequenced-spiral learning and content, inquiry-based practices, and 21st century skills development.

Structured-sequenced-spiral learning and content. Student notebooks showed how the curricula spiraled to allow students to explain, evaluate, and elaborate. A sequenced or spiral curriculum is one in which a subject, topic, or theme is revisited several times, with the complexity of the topic increased with each visit so the new learning is connected to the old learning (Gibbs, 2014, p. 41). Evidence of spiral and sequenced lessons was found in Student
Guides (the inquiry-based curricular “textbook”) and student notebooks. The concepts taught were sequenced and spiraled to deepen learning until the end of the module.

The investigator noticed how the students were taught a systematic way to organize their notebooks in grades 7 and 8. It included a table of contents or description page, chronicled sequentially with dates and page numbers in order to easily locate the content learned. As evident in the notebook, the concepts were introduced, then structured for students to grasp and build upon. An example of spiraling was found from seventh grade to eighth grade, in studying mass and weight. In seventh grade, students encountered these terms when learning density, then again in eighth grade, when learning about energy, motion, and lights (See Appendix Q).

The curriculum spiraled with physical science (properties of matter), life science (life cycle and genetics), earth science (storms), and space science (planets). The human body curriculum was the only curriculum that did not begin at the lower elementary level to spiral learning through 8th grade.

**Inquiry-based practices and 21st century skills development.** Inquiry-based practices were found to be used by students in the learning process. This revelation was expected, considering that inquiry-based learning was the rationale for this change. Inquiry-based practices included: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in arguments from evidence; and obtaining, evaluating, and communicating information (*A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, 2012). Interviews, documents, and curricular materials corroborated these practices as being included in lessons along with 21st century skills. Twenty-first century skills—creativity, critical thinking, innovation, collaboration, communication, and problem-
solving—(Partnership for 21st Century Learning, 2009) were not directly being developed, yet these skills were being employed as students acquired content knowledge through inquiry practices. Below are descriptive findings on 21st century skills embedded in inquiry-based practices during meaningful lessons:

*Asking questions-problem solving-collaboration-communication-creativity-innovation.*

Each lesson began with a question for the students to explore. Students worked in groups to come up with ideas on how to answer the questions being investigated. They listened to each other’s reasoning, then discussed the direction the group should take (Partnership for 21st Century Learning, 2009). They were able to create new and worthwhile ideas using real world experiences as evident in student projects.

*Developing and using models-critical thinking.* When given a picture of a balance, a second grade student in Hannah’s class was challenged to draw objects on it that corresponded with the placement of the fulcrum (See Appendix K).

*Planning and carrying out investigations-critical thinking-communication-collaboration-problem solving.* Because students were charged with devising a procedure to investigate a question, these skills and practices were intertwined. Evidence was revealed in student notebooks. Students at the elementary level were asked to write a procedure to screen river rocks using items included in a picture they were given (Appendix K). At Middle School 6-8, the students were asked to identify variables to determine what to control in the investigation, then discuss how that specific variable affected the data collected. In addition, critical thinking and problem-solving skills were used to carry out the investigations.

*Analyzing and interpreting data-critical thinking-communication-problem solving.* Students often used graphic organizers, such as Venn diagrams, tables, webs, and charts to
analyze data collected. Hannah’s students used a Venn diagram to compare and contrast a beam balance with an equal arm balance (See Appendix K). In Middle School 6-8, an example was finding the surface area to determine how the force of friction is affected (see Appendix Q).

*Using mathematical computational thinking-critical thinking-communication-problem solving.* Students used patterns and measuring tools to make mathematical comparisons and think quantitatively about the data collected, such the examples given above a unit in which the students compared the sizes of rocks in Grade 2. They also demonstrated this practice using patterns to make mathematical comparisons in “The Story of the Sand” before communicating their results in writing (Appendix K).

*Constructing explanations-critical thinking-communication.* All investigations concluded with written explanations to communicate what was learned from the investigation. For example, when Hannah’s students weighed cupfuls of food, they compared the results to predictions they had made before the investigation. (See Appendix K) “Reflections” found in a student’s notebook in Middle School 6-8 provided evidence on the use of these skills at the conclusion of the investigation (see Appendix M).

*Engaging in arguments from evidence-communication.* The dynamics of the groups, as previously described in this chapter, provided evidence of these skills and practices.

*Obtaining, evaluation, and communicating information.* Students developed their abilities to take scientific information from text and communicate what was learned. Because students had to research information for projects, this information came from books in learning centers, library, internet, or curricular texts.
Summary of Rationale for Change

The rationale for changing from the old approach to teaching science was to ensure that students would be learning science using best practices aligned with national science standards. The two goals were to increase student engagement through meaningful learning and to teach science content and 21st century skills using inquiry-based practices. Teachers provided meaningful learning using a repertoire of instructional strategies to engage students: outdoor experiences, projects, learning centers, science literature, and groups. Furthermore, lessons were structured for students to grasp and build on: the lessons spiraled and were sequenced. Moreover, inquiry-based practices and 21st century skills were found to be interwoven to enhance student learning.

Implementation Process

The implementation process was critical to attaining the desired goals. Although the curricular goals were met, obstacles had to be overcome in order to implement them. This section describes findings about the processes that were undertaken: (a) choosing the curriculum, (b) professional development initially lays a strong foundation, (c) overcoming internal and external obstacles, and (d) post-implementation process.

Choosing the Curriculum

Dr. Simon intentionally fostered collaboration with school leaders during the transition. According to Dr. Simon, “the first process was to educate the administrators and staff about inquiry-based science, and what it is and what it is not.” This process secured buy-in with school leaders before bringing teachers aboard. In order for the promotion of inquiry-based science reform to reflect that of the National Science Foundation and National Science Research Center, the second step was “to acquire the materials that promoted inquiry, meaning students doing
science, rather than reading about it or making pictures of it, and then professional development” (Dr. Simon).

After an evaluation of the existing curriculum and making comparisons against best practices (Dr. Simon), three inquiry-based programs aligned with the desired goals of ATSD were selected by the team: Full Option Science System (FOSS), Science and Technology Concepts Program (STC™ Program), and LAB-AIDS. All modules of the curricula included consumables and had to be refurbished at the end of the school year. FOSS and STC™ Program curricula were used in grades 1-5, while Middle School 6-8 used STC™ Secondary Program and Lab-Aids. The objectives of each program are shared below.

**FOSS.** According to the FOSS website,

The FOSS program materials are designed to meet the challenge of providing meaningful science education for all students in diverse American classrooms and to prepare them for life in the 21st century. Development of the FOSS program was, and continues to be, guided by advances in the understanding of how people think and learn. FOSS provides all students with science experiences that are appropriate to students’ cognitive development and prior experiences and its design is based on learning progressions that provide students with opportunities to investigate core ideas in science in increasingly complex ways over time (Lawrence Hall of Science, 2015).

**STC™ Program.** The Science and Technology Concepts Program (STC™ Program) was developed by the Smithsonian Science Education Center (Smithsonian Science Education Center, 2015), based on research into how students learn best:

It is a basal, inquiry-based science curriculum for grades K–10 that covers life, earth, and physical sciences with technology. STC™ Secondary Program builds on the skills and
knowledge developed in the STC Elementary™ curriculum. STC Secondary™ program is aligned with National Science Education Standards (NSES) of the National Research Council (NRC). (Smithsonian Science Education Center, 2015)

School K-2 uses its modules to study “Balancing and Weighing” in second grade. In grades 6-8, the modules are: Organisms from Macro to Micro, Properties of Matter, Catastrophic Events, and Energy Machines and Motions.

LAB-AIDS®. LAB-AIDS® is an inquiry-based curriculum that has been in existence for over four decades. It is used in Middle School 6-8 to study genetics.

It was established by a Long Island, NY, science teacher who knew that when students experience science first-hand they are more engaged and have greater knowledge retention. This curriculum helps science teachers offer a more meaningful "hands-on" experience in the classroom by providing them with the materials and equipment that they need to execute actual science experiments with their students, making learning more effective (LAB-AIDS®, 2015).

After the decision was made to use these programs that were aligned with science standards that include a focus on inquiry, the next step was to provide professional development to staff members “to really to focus on developing the capacity for change and leadership… not to immediately go out and purchase stuff and drop it in classrooms, but rather to do professional development, teach your leaders about what to expect when you implement change” (Dr. Simon).

**Professional Development Initially Lays a Strong Foundation**

School leaders and teachers were sent to local colleges and universities to be trained on the modules that were part of the selected inquiry-based science curriculum, as would teachers
hired later. Eventually, the trainers were brought into the schools to professionally develop other teachers. In these early phases of the program, professional development (PD) provided a strong foundation. Participants from each school lauded this process as being essential to making the transition seamless. Esther recalled that “providing teachers the professional development so they were comfortable and aware of a new transition from traditional to inquiry-based science was key.”

The teachers shared how curricular trainers came in, as well as how all teachers were sent to a local university to receive training on the FOSS and STCTM Program science modules. Sarai recalled:

When I started, we had very little budget issues. The district sent me to a local university to take classes with master teachers who had studied these curricula, who had developed lessons, and who had extended those lessons to help teachers understand how to teach inquiry-based science and make each lesson the best it can be. For all the modules, I was trained at the local university.

Mary, Lois, and Vashti corroborated:

The trainers from the company came out and trained the teachers (Mary). They actually brought in an outside trainer to train teachers on the units, a full day training (Lois), really taking them through the entire module and just walking them through the process so that we can do the activities with the trainer and get that hands on experience, so that we knew what to expect before we taught the kids, which was very helpful (Mary). This was good because then it was very hands-on and I got to actually do the experiments (Vashti).

In contrast, Hannah at School K-2 stated, “I was currently teaching kindergarten. I'm not privy to the module training. I want to say they had someone come in… I want to say a
representative came in and went over them.” This statement was surprising to the researcher because Dr. Simon claimed the program began in grade K. Hannah’s account was corroborated by archived documents. These documents show that the ATSD inquiry-based 2005 curriculum guides were for grades 1-8. Kindergarten was not found in the archive.

Nevertheless, PD began as a strong foundation to build a successful and sustainable program to meet the desired goals. Training was hands-on and teachers felt prepared to teach the modules. Soon afterwards, PD was weakened by internal and external obstacles that needed to be overcome.

**Overcoming Internal and External Obstacles**

Several internal and external obstacles were among the findings: there was unequal access to the curriculum, not all parts of the curriculum were inquiry-based, assessments were not aligned with inquiry, there was less scheduled time to do inquiry; and external funding was cut.

**Unequal access to inquiry-based curriculum.** The study revealed that not all had access to inquiry-based teaching and learning, specifically special education teachers. Special education teachers in School K-2 did not receive the science modules. When Hannah began to work as School K-2 head science teacher, she discovered the gap:

Special need classrooms didn’t have the modules. They don’t really have access to science things at the lower elementary level. I can only speak for second and down. I don’t know how it changes once we get to third. They do some science activities in their classrooms, but they don't seem to be included. I'm talking about the self-contained. (Hannah)
In public education,

Self-contained is a classroom that has a fewer number of students in a smaller setting in order to meet the individual needs of the students. The teacher holds a certification in special education. Most special education teachers receive training and education in a specialized area to meet individual special needs. This classroom also has a paraprofessional who provides instructional support under the guidance of the classroom teacher. (Chen, 2015)

However, at School 3-5 and Middle School 6-8, all lessons were modified to meet the individual needs of this particular population. In those schools,

Our POR (pull out resource) classes, where the kids are pulled, they do use the same kits for science. So they are exposed to the same content, same skills, which is good, but they're modified based on their needs. So, everything they need is there, it just has to be adjusted based on what the kids need. (Mary)

Phebe of Middle School 6-8 explained that she is “doing the same curriculum just at a slower pace,” and that she thinks inquiry-based teaching is beneficial for students who receive Special Ed… “Because they're not just looking at it, they're not just hearing it, they’re using all their senses and I think that is a key way for the Special-Ed students to learn” (Phebe).

Not all parts of the curriculum were inquiry-based. If the curriculum was not accessible to all students, this implies that the traditional approach was still being used. Due to the fact that all parts of the curriculum are not inquiry-based, teachers had to find other resources to teach science. Teachers have flexibility to teach content using old textbooks, as well as resources found on the internet, as long as they are meeting curriculum standards (Hannah, Ruth, Sarai, Phebe, Lois, Vashti)
Although Dr. Simon stated, “We engaged in a process of revamping our science curriculum K through 8”, as previously stated, interview and documents prove otherwise. According to Hannah,

In the third trimester of kindergarten the students study the life cycle of butterflies and in the first two trimesters there is not a set science curriculum. We didn't have our science curriculum in Kindergarten, but I researched and borrowed some from companies so my classroom always had it.

In first grade, they studied the life cycle of lady bugs (see Appendix K) along with the inquiry-based modules. Life cycles of the butterfly and ladybug units are not part of the inquiry-based curriculum. *Insect Lore* is not an inquiry-based program; it is a traditional approach to teaching science (See Appendix K).

Further accounts were given to underline that not all parts of the curriculum were inquiry-based. Sarai wondered why students were coming into the middle school as if they had not been exposed to inquiry.

I think they have an idea what inquiry-based is, but I don't think it's being taught properly because if it was being taught properly, I think kids by the time they reach sixth grade they would have more science skills, application skills, processing skills, willing to make their own discoveries, not just waiting to be spoon-fed information. (Sarai)

Ruth explained with disappointment how she spoon feeds,

I have tried where I would give a procedure and I would think that they can handle it well, then after 10 minutes of juggling around with materials, students all confused and don't know what to do, when it seems that it's written pretty much in an easy way, that they do struggle and I have to either model it or read the procedure. Then it's not inquiry-
based, it’s teacher directed activities. There are a number of times that I have done teacher directed activity.

Eva of School 3-5, a prior first grade teacher, stated with worry what she sees with her students coming from School K-2: “…because science from grades K-2 are just exposure and whatever. That is a roadblock I have, getting these kids to actually be thinkers and workers in science when they come to third grade.”

Another factor is the lack of science kit refurbishment, resulting in less exposure to inquiry-based learning.

And then we're doing ecology, which we're not doing really ... We don't have the inquiry-based program so it's what all the teachers are putting together and some people are doing the same things, some people are doing something different. That also, I think we need to work on. Once we get into the other units, so the volcano unit, which is an inquiry-based, but which we don't have all the material so we only do a couple of the labs; I don't think we were meeting the proper standards for them to learn through inquiry-based. So I think they're learning more paper and pencil packets, which I think is something that we need to get away from. (Phebe)

Considering that the curriculum was not all inquiry-based, findings revealed that the assessments reflected this gap in instruction; however, teachers used various assessments to gauge learning.

**Assessments not aligned with inquiry learning.** Formative and summative assessments were used as part of the inquiry-based program in ATSD. Teachers created their own written formative assessments for quizzes, as well as end of chapter or unit tests, although written and performance assessments were provided with the inquiry-based curriculum that had been chosen by district stakeholders. The assessments that came along with the program were summative, and
from “my understanding, as designed they are meant to measure both process knowledge and understanding, and the big ideas of the content that the students are to glean from the kits” (Dr. Simon). A review of the teacher’s guide found suggestions on how to formatively assess student work before the end of the unit. Contrary to these suggestions, teachers created their own assessments, which could be problematic because assessments were not aligned with how students are learning science through inquiry. Assessments were based on the traditional approach to teaching science.

Some teachers appear to gravitate more towards their teacher-made tests, which were more rote, low-level knowledge. I do recall, because my children go to the schools, I do recall seeing supplemental assessments coming home that were much more content driven, actually a little more content driven than I would have liked, little fill in the blanks and multiple choice. (Dr. Simon)

At this point it is important to explain the “why” behind the continuous use of pencil and paper, teacher-made assessments. The practice of giving these kinds of tests evolved from ATSD instructional policy. According to policy (See Appendix N), in addition to class work and homework, a minimum number of assessments must be given each marking period. Each school had its own policy. For example, the policy in Middle School 6-8 is, along with grades from class work and homework, a minimum of two tests and four quiz grades were weighted to determine the quarter-term grade. However, if only the test from the curriculum was administered, it would result in one test per grading term because usually it took more than a term to teach a content unit.

For School K-2, “nine are required for second grade, at least. It was nine actual grades in PowerSchool. Whereas in the past…teachers fill in an O or S at the end of the trimesters. Science
is still an O or S at the lower elementary” (Hannah). O is for outstanding and S is for satisfactory. Consequently, in order to meet policy, teachers often resorted to using their teacher-made tests, in addition to informal assessments.

**Informal assessments.** The participants described that they assess informally while the kids are doing labs. “I keep a clip board. I can take notes on who's doing what, who’s being really hands on; who's not participating…” (Hannah) “I walk around with a little sheet and write down if they're on task, if they're following directions, if they're doing all that.” (Vashti) Students collected work samples for their portfolios that represented what they were supposed to learn, so the teacher that had the checklist would say, show me something from your portfolio that shows this, the student is able to verbally speak about the sample, so we had both, the portfolio and oral conversation as an assessment (Mary).

Mary further shared:

I know that in third grade, we had an assessment that focused on the process, not so much the terminology or the concepts. It was, here are the steps, find three flaws. They would say, "You can't use the toothpick that you used for this chemical and dip it into the other chemical because that's contamination." So they were able to apply what they learned, so that's the process.

The other one would be the end of module assessment. You have the right and wrong answers, a lot of times the teachers were able to ... if the students were supposed to explain their thinking, even if it's not exactly what happened, but if you can see their rationale and their thinking behind the science process, they would give them credit for it. So it's not so black and white.
Eva corroborated:

Unfortunately, our kids have not been trained to be thinkers and it's too much effort for them to think. I reward effort, not necessarily answers. So even if it's not nail on the head, this is what we're looking for, if it's going along the route that there's been some process of why did you think that, you know? I always gave either credit ... Verbal credit for it to be a no-risk situation you know? Any answer that had some thought and had some reasoning is a valid answer for me and I don't want anybody to be embarrassed...if it's dead wrong, as long as they had effort, I try to reward that.

**Performance assessments.** Performance assessments allow students to demonstrate the skills and content learned using an inquiry-based approach. A performance assessment is where we step them up [challenge them more] ... They actually have to do stuff and logically show the progression of why they did it and what their outcome was (Mary). These particular assessments were part of the STC curriculum (Dr. Simon); therefore, all schools had access to these assessments, even if they were not being used by teachers.

Providing assessments that were not aligned with how the students are learning was problematic for determining if the program was successful and sustainable, and for formatively assessing the goals of acquiring science content and developing 21st century skills. Ruth posed two questions that are worthwhile to ponder:

When we do this project-based learning, trying to do more independent projects where you are trying to test their scientific skills, engineering practices, how to quantify that? That's something ... how can I be fair to student who might not have good content knowledge but have really great creative skills and have creative ideas to solve the problem?
Although assessments were not aligned with how students were learning science, teachers understood the need to gauge learning differently, taking into account the various assessment approaches—projects, teacher-made, informal, pen and pencil, and performance. “Whenever they're able to do it actively, hands-on, you're able to get a different perception as to what they really know and can do” (Jared).

Less scheduled time to do science. Teacher and school administrator participants concurred that there was not enough time scheduled to teach science. Ruth stated, “As we transition into inquiry-based, we have enough material but then we don't have enough time. Something always lacking…we talked about the amount of content that we want them to learn and the skills we want them to develop, there's always the limitation of time”.

Science was taught daily only at Middle School 6-8, whereas at the elementary schools, it was rotated with social studies. In School K-2, science was taught three times a week for 40 minutes and this time was shortened by the mandatory recess time. In third grade, science was taught during two of the three quarters for 90 minutes. In fifth grade, science was taught half the year for two one-hour blocks.

Jared, School 6-8 vice principal, shared:

I don't think it's enough time. The teachers have 60 minutes to teach science every day for 180 days. Obviously, you're taking into consideration some days that are lost on time for certain reasons. An inquiry-based program, based on what I've seen and the feedback that I've been given, it's tough to do it effectively or maximize an inquiry-based program with 60 minutes because as you know, there are already things that a teacher needs to do before they even get to the meat of the lesson as far as assessing students, homework, providing feedback on that homework, getting to an anticipatory set or a warm-up. That's
why we are looking into different options for scheduling, increasing the amount of minutes per period.

The issue with that would also be that it may not be a full year course, but at least if you have more minutes in a particular class, you're able to not have to piecemeal your lab activities and review the next day to the extent that you're doing now because you're able to incorporate more into one class period and just accomplish more in, let's say an 80-minute period than you would in a 60-minute period. It's different things we're looking into as well to benefit the science program.

Hannah shared, “Everyone's guilty of occasionally just ... We need to get through this lesson. We just need to get through this lesson. This year I made that time fit no matter what.”

Eva talked about what it takes to prepare to teach science:

So you know it makes it a little more challenging, and it's hard being in a classroom to all of a sudden jump from language arts, get your stuff together, it's intense. It's not like, "Okay, there's a lab sitting waiting for you." You know, you got to set it up, you got to clean it up, you got to break it down and then manage it. It's a lot to cover in an hour.

Then sometimes when you're doing the review ... It's not an easy juggle.

Lois shared:

I think that that we only do a half year of science is a disgrace. It's very difficult to fit in. I was here when we were doing a full year of science. Science is what I enjoy the most, so to me, only doing a half a year allows you to just push too much in. What ends coming out are the more open-ended inquiry-based things.

Vashti calmly, but firmly, stated:
I think it would be nice to do science every day. We only do two marking periods out of the year. They're only getting 90 days of it. I think it would be better to do it all year. We do three units, so we only have 30 days for each unit, or each module, I should say. It's very rushed. This is what we're doing, this is what ... Very rushed, very rushed.

Time to do science was taken away. Mary explained:

There was this big push for literacy, so we increased the time for literacy and that time has to come from somewhere. It was taken from science and social studies. It was taken away but the time we teach science and social studies, during those designated marking periods, increased a little bit. It's not ideal when you talk about science, but when you talk about the need as a district, because our kids were not reading on grade level, and yes, they were struggling.

The push for literacy may have resulted in teachers pushing science backwards. Dr. Simon explained, “I did over the years, hear concerns that in certain classrooms, some of the kits would come back [for refurbishment] and they weren't touched or they weren't opened.”

Science has taken a back seat to math and English language arts (Phebe, Lois, Mary, and Hannah). As a result, science became more hands-on, paper and pencil, teacher-led, and textbook driven as opposed to being inquiry-based. According to memos, the investigator noted that hands-on was used often used, seemingly, interchangeably with inquiry. Hands-on approach is different than inquiry-based. Inquiry-based does not exist without being hands-on, but hands-on can be done without inquiry.

**Funding cuts.** In 2009, approximately three years after full program implementation, ATSD “loss over three million dollars in state aid” (ATSD 2012-13 School Budget PowerPoint). The devastating results were the elimination of programs and services; increased class sizes;
reduction in supplies, equipment, and technology; and personnel cuts (22 teaching/certificated positions, 10 support staff, 49 aides, and 3 administrators). Dr. Simon reflected on this particular time during the interview:

In an age of two percent property tax levy caps, everything gets squeezed, and unfortunately, some things get squeezed more. The things that squeezed more are things that matter the most. If a company cut their R and D budget in the ways that schools cut their R and D budgets, the company would be out of business… Many of those positions have disappeared. Many of the resources have disappeared. Our biggest obstacle is a devaluing of R and D, or professional development, curriculum development, promotion of best practices in education.

Post-Implementation Process

The budget crisis inevitably left the district leaders and school leaders in an awkward position of continuing an inquiry-based program without close monitoring and worthwhile PD. On the other hand, not having these resources increased collegial collaboration. The remainder of this section describes the lack of ongoing monitoring, turn-key professional development, and increased collegial collaboration in greater depth.

Lack of ongoing monitoring. Cutbacks in funding affected the program on all school levels. The impact of the elimination of the science supervisor was the initial start to this snowball effect. Before the budget crisis, a science supervisor monitored science in all schools. Several participants recalled Mr. Tolliver (pseudonym), the former science supervisor, as very supportive. “Mr. Tolliver had a science background. I felt like he had more knowledge and cared more about the subject. There is no longer a supervisor of science who possesses science knowledge” (Sarai).
Due to budget cuts, the position was not filled when Mr. Tolliver retired. The responsibilities of this vacancy became an additional task of the school building administrator, along with their daily responsibility of managing their buildings. Esther spoke candidly about the challenging task of wearing hats of both administrator and science supervisor. “They [teachers] would come to the administration for support and answers on, how they really create systemic lessons that challenge student learning? That was always a challenge because we didn't have the answers at the time either. We were learning through the process ourselves.”

**Turn-key professional development.** After the budget cuts, turn-key professional development became the norm. Instead of being sent to colleges and having professional trainers come into the schools, “many of the things we do are turn-key, to the best of our abilities” (Jared).

According to Rouse (2005), in training, a turnkey is an employee who has been sent somewhere to learn a specific skill. The turnkey is expected to return and share what they have learned with other employees. The turnkey becomes a trainer who turns the keys (of knowledge) over to someone else. In this context, turnkey is used as a verb to describe the imparting of this knowledge by teachers.

Nevertheless, Sarai and Mary recounted the differences in the quality of PD. Sarai stated, “After that big budget crisis, it [PD] just stopped. I know a few times I had to train teachers on modules, which is fine, but I didn't feel like I had mastered the inquiry-based curriculum. I don't think I was very effective in helping teachers understand the inquiry-based curriculum.” Mary described the training in School 3-5:

So now the PD continues, where we have new teachers come in, or when we have substitutes come in. We take the science head teacher, or someone in each grade level
who is pretty comfortable and likes science, and we give them time during the school hours to sit with them. Whether it be during faculty meeting, PD time, providing coverage or even over the summer. People volunteer, or we pay them, and they provide that one-on-one training, but that kind of the training is really the teacher's version, "here's what I do," which is kind of different, because it's not an all-day thing. It's a truncated version to make it work, so that's the kind of training that happened.

Vashti recollected how she received the “truncated version” when she changed grades. “I had to learn the fifth grade units, it was just another teacher giving me this stuff, and showing me real quick. I didn't really get the professional development for these modules like the other ones” as a result of turnkey training.”

Hiring someone to come in to offer training is beneficial (Jared, Mary), because a lack of ongoing PD affected pedagogical practices and the learning of science ("Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy," 2009). However, it was costly and the resources were not available (Jared, Mary).

In the 2012-13 school year, three years after the 2009-2010 funding cut, the School K-2 vice principal position was restored and $37K was added to the budget for curriculum support and PD (ATSD 2012-13 School Budget PowerPoint). As participants corroborated, Science PD, as it was in the initial phase of the transition, had yet to be restored.

**Increased collegial collaboration.** In spite of all of the obstacles, collegial collaboration was heightened. Participants shared how they counted on each other for guidance and teaching strategies in order to fill the gap of not having a supervisor and worthwhile PD. Although the schools had science clusters or head teachers, they relied on others due to how collaboration time was scheduled.
Each school had collaboration time, which is called “common planning” or “team time.” During this time, teachers shared and discussed lesson plans, ideas, and teaching strategies. This time was built into the schedule and looked different in all schools.

In School K-2 teachers were provided a common planning time (Esther, Hannah). This was the first year that teachers in School K-2 were given time to collaborate. Hannah described how common planning takes place within School K-2:

They normally provide us with some time to get together during the professional development days, or faculty meetings ... They’re pretty good about that. That's something we requested a few years back, and we definitely get more together time now. This year we were given a common planning schedule, which was--we’re on a six day cycle. One period every, once every six-day cycle you will meet with a group. Unfortunately what we found is, I was in a group; second grade teachers and there were six of us. I think there's twelve second grade teachers. So, it's six of us, and that's on day two. But on day one, were the other six second grade teachers. So it felt like the other five people in my group, we would stay on the same page. The other group of common planning would sort of stay on the same page, but our pages could be completely different between the two groups.

Hannah used another method to share with the teachers. “I was compiling a binder for them. So, they have one resource. Last year, just for fun on my own time, before being head science teacher, I had actually made a teacher's manual for second grade.” As validated by Esther,

The head teacher has put in the faculty room a binder that actually has a lot of the lessons that are being done here so that you could share collaboratively and what you're doing in
your classroom could also be shared in another classroom. So, the collaboration really is the key. It's really sparking a major interest and passion, learning more about the inquiry-based science.

In School 3-5, “they don’t get much time.” (Vashti), Eva shared:

Well, we do have common planning once in a six-day cycle if it’s not a half day.

However many times there's an agenda that they're trying to impart information ... And that is only half of a grade so it's not all sharing. I know this is going on record, but when the grade meets as a whole, there are some stronger personalities that always prevail, and all they want to do is complain. They don't want to solve. That being said, I'm not going to say any more about that. But, there's a lot of collegial sharing for modifications. So that's really good here.

Lois, who is described by Vashti as the science go-to person in her building because she “usually acts as the fifth grade supervisor for science,” shared her concerns about common planning time:

It's difficult because we have a common planning, but my common planning is not with all the other fifth grade teachers. So, the only opportunity we have to discuss is when we have in the staff meetings and it's a Professional Development days. And, I as the voice for fifth grade will request that we get time to talk about things. It's not automatically thought of that we would need that time. (Lois)

Describing how they collaborate, Lois explained,

I'll go to my other peers and say, ‘What are you guys doing with this?’ Or ‘I was thinking of trying this new ... Do you think it would work?’ Then we can talk about pitfalls and
stuff. We work very closely together as a team, and we've been together for a long time.  

There's just one or two new people.  

Collaboration was the strongest at Middle School 6-8 because of the way it is scheduled. At the middle school, this time is called team time. Jared, Ruth, Phebe, and Sarai explained how it works. Jared shared:

We like to provide teachers with as much opportunity during professional development time, during faculty meetings. We like to offer a department time during those time periods. During team time, teachers have 4 out of every 6-day cycle, they have the opportunity to meet with their team teachers. It doesn't necessarily mean that they meet with their subject specific teachers. That's why last year, we were able to come up with a schedule in which grade level departments meet bi-monthly. They'll meet at least twice a month to discuss curriculum, to discuss programs, to share ideas, and just to collaborate over all the assessments and those types of issues.

Ruth said:

We brainstorm and we get feedback from each other almost every day. Weekly we meet ... we meet at least once per week, not per schedule, as scheduled we do meet once per two weeks at the science meeting, but apart from that, we do meet quite often and it's working. I find something, I share, if they have anything, they share. The collaboration is excellent. Overall, inquiry-based program actually make us more of a community of educators because you talk about what was successful in your class today and what worked well for you. We depend on each other.
Phebe added:

Well we have team time, and we also have cluster time for science. So I think we meet once a month, but you can talk to teachers all the time. Science teachers all talk, the Special-Ed teachers talk, we all talk at any time. So I think that's the one nice thing we have here, we do have that time to talk.

Sarai remarked: “We team plan, and every two weeks we have department meetings, but with all the other things we have to do sometimes, we don't get to meet at those times. Really, I guess twice a month.”

In spite of the described internal and external obstacles, collegial collaboration has had a pivotal role in sustaining the program.

**Summary of Successes and Shortcomings**

The rationale for the change was to ensure that the curriculum was aligned with national science standards for students to learn science using best practices that would prepare them with not only science content, but also with 21st century skills. As a result, two goals were achieved: meaningful learning to increase student engagement and the acquisition of content knowledge and 21st century skills development using inquiry-based practices.

Findings show that ATSD has taken “a step in the right direction” (Hannah) to achieve these goals. Evidence on student engagement in meaningful learning and instruction included the following: (a) content was presented in diverse ways; (b) content was sequenced, spiraled, and structured to cognitive abilities in order for students to build on previous knowledge; (c) inquiry-based practices and 21st century skills were not learned in isolation; they were intertwined.
To produce these effects, several processes occurred; some were successful and others proved to be obstacles that had to be overcome. The successes included: (a) choosing an inquiry-based program that met the need to promote inquiry-based learning, (b) teachers were provided with PD on the chosen curricula before full implementation, and (c) increased collegial collaboration resulted.

Unfortunately, the obstacles outnumbered the successes: (a) there was unequal access to inquiry-based curriculum, (b) not all parts of the curriculum were inquiry-based, (c) assessments were not aligned with inquiry learning (d) there was less scheduled time to do science; (e) funding was cuts, (f) there was a lack of ongoing monitoring; and (g) turn-key PD was not enough. Given these obstacles, as well as the few successes, more “steps in the right direction” are needed.

Conclusions and implications drawn from these findings are discussed in the next chapter.
Chapter Five: Conclusion

The purpose of this descriptive case study was to engage with multiple stakeholders to formatively assess the implementation of an inquiry-based, K-8 curriculum designed to help students learn science content and 21st-century skills. The research questions were: How does the implementation of an inquiry-based program within Areal Township School District (ATSD) support the acquisition of science content knowledge and the development of 21st-century skills?

a) What was the rationale for the program?

b) How well did the program meet its desired goals?

c) What was the transition process like?

This chapter is organized using the program logic model, “Implementing Inquiry-Based Science in ATSD,” which was presented in the previous chapter: (a) research context and participants, (b) rationale for change, (c) desired goals, (d) implementation process, and (e) successes and shortcomings. Reviewed literature is referenced throughout this chapter, and the findings are related to Bruner’s constructivist framework.

Discussion on Research Context and Participants

This section provides an overview of the research context and participants to better understand the significance of the study within its context. The case unit included all the elementary and middle schools in ATSD. The district is a melting pot of learners: special education, regular education, diverse ethnicities, socioeconomically disadvantaged, and English language learners. Participants consisted of the former superintendent, a principal, vice principals, and special and regular education teachers of science who provided in-depth views that illuminate this phenomenon.
Discussion on the Rationale for Change

During a time of science reform efforts, ATSD was still using “textbook-driven and knowledge driven practices that did not align with national science standards” (Dr. Simon). Because these practices did not align with the best practices on how students learn science, which is through inquiry (National Research Council (U.S). et al., 2005), the decision was made to change the program. The rationale for change was communicated as not only a local need, but also and more importantly, as a national need. A transformational approach was taken by placing the need in a much bigger realm than that of ATSD, to minimize resistance to change (Burke, 2008). To be aligned with national standards means to also be aligned with their goals.

Discussion on Meeting Desired Program Goals

ATSD established goals based on the 1999 national science standards and best practices. Since that time, the state has adopted new science standards, the Next Generation Science Standards (NGSS). Despite this adoption, the goals are unchanged: students still need content knowledge to be prepared for college, careers, and citizenship. For this endpoint, ATSD set two goals: meaningful learning to increase student engagement, and using inquiry-based practices to increase science content knowledge and develop 21st century skills. Both goals are underscored by Bruner’s constructivist framework on how students acquire knowledge.

Meaningful Learning

According to Bruner’s constructivist framework, a characteristic of effective teaching is that instruction relates to experiences and contexts to make the student willing and able to learn (Culatta, 2013), resulting in a readiness to learn. In other words, meaningful learning begins with the engagement of students in various ways that are relevant to their experiences and environments. These meaningful engagements included “practices, such as building, refining,
and applying scientific knowledge, to understand the world, and not as rote procedures or a ritualized ‘scientific method” (A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012, p. 254). In practice, teachers in ATSD used outdoor experiences, projects, learning centers, and groups. All approaches are child-centered, and students are learning by doing (Dewey, 2004).

**Outdoor experiences.** Hannah’s students worked outdoors to plant wildflowers prior to the unit on plants. Doing this provided her students with an experience that could be used to refine concepts in the classroom and apply scientific knowledge, thus utilizing meaningful practices (A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012).

**Projects.** The projects were relevant to the concepts being studied and included choices to meet diverse learning styles and allow students the freedom to be creative. The students were able to demonstrate what they learned through projects, even though it was not project-based learning, “an approach to instruction that teaches curriculum concepts through a project” (Bell, 2010, p. 41). Teachers were not using the projects to teach, but using them after concepts are taught, which Dr. Simon described as “kids were doing activities about science, but not wondering about some phenomenon and then developing an experiment, then trying some things out.” Students continued to be engaged using this instructional approach even though it was not aligned with the rationale for change, for students to learn science using best practices. Projects were one of the most highly used instructional approaches aside from the inquiry-based curriculum.

**Learning centers.** Unlike projects, the science and literacy centers were set up for students to further investigate as active learners and build on prior knowledge (National
Research Council (U.S.). Committee on Defining Deeper Learning and 21st Century Skills. et al., 2012). This kind of engagement minimizes the role of teacher-led instruction since students have the freedom to explore on their own. The literacy center is a place where students could work independently, whereas at the science center in Hannah’s class, students were expected to visit in a group of two.

Groups. All teacher participants favored students working in groups. In inquiry-based classrooms, this approach encourages student-student interactions and learning from peers. Bruner initially asserted that this learning could be done intrinsically. However, he expanded his theoretical framework to include the social and cultural aspects of learning (Culatta, 2013) after being influenced by the work of Lev Vygotsky. Bruner then noted that a child's social environment and social interactions are key elements of the learning process (Firestone, 2014). Students have roles and responsibilities; consequently, their taking active roles in their own learning allows the teacher to become a facilitator of student learning. Groups underscore Bruner’s assumption that communication and collaboration are fundamental to learning.

Science Content and Skills Development Using Inquiry-Based Practices

Meaningful learning was found to be the basis for students to acquire science content and 21st century skills development using inquiry-based practices. Structured-sequenced-spiral learning and content, inquiry-based practices, and 21st century skills play pivotal roles in the learning process, as discussed in this section.

Structured-sequenced-spiral learning and content. Inquiry-based practices and 21st century skills development were evident when students were engaged in learning that was structured, sequenced, and spiraled. Bruner argued, “Grasping the structure of a subject is understanding it in a way that permits many other things to be related to it meaningfully” (as
cited in Deng & Luke, 2008, p. 75). ATSD teachers used various ways to ensure that students learned according to their abilities. Science content was organized and revisited using different instructional approaches and contexts. The idea of structure was emphasized in inquiry and problem solving curricula that focused on in-depth exploration of smaller, illustrative units of content that allowed generalizations to be drawn (Franklin & Johnson, 2008, p. 463) Student notebooks revealed that each lesson had several components for learning the same concepts by performing different activities. “Quality instruction will have students engaged in several practices throughout instruction” (NGSS Lead States, 2013a, p. xiv). According to Bruner, this structure is characteristic of effective teaching.

Science concepts spiraled from previous grade levels to be later introduced in a different context. Bruner referred to this sequencing as a spiral curriculum—another characteristic of an effective instructional approach. “A spiral curriculum is one which a subject, topic, or theme is revisited several times; the complexity of the topic increases with each visit so the new learning is connected to the old learning” (Gibbs, 2014, p. 41). Not all lessons were inquiry-based, yet student notebooks showed the spiraling and structuring of concepts that were built upon so students could acquire content, practices, and skills.

Inquiry-based practices and 21st century skills development. The study found that when students were engaged in inquiry-based learning, 21st century skills were being developed. This finding is consistent with the research of Minner et al. (2010). The integration of these practices and skills was essential for meeting lesson objectives and likewise for college and career preparation. In other words, “Students need to make sense of their world, and approach problems not previously encountered—new situations, new phenomena, and new information. To achieve this level of proficiency, students need a grasp of key science concepts and the ability to
relate that knowledge across disciplines” (NGSS Lead States, 2013a, p. 348). The intertwinement of these skills and practices were evident in each of the different parts of the lesson, from the focus activity until the conclusion of the lesson. All inquiry-based practices and 21st century skills were used: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in arguments from evidence; and obtaining, evaluating, and communicating information (A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012); as well as creativity, critical thinking, innovation, collaboration, communication, and problem-solving (Partnership for 21st Century Learning, 2009).

Bruner postulated that individuals construct knowledge and interpret the world mostly in terms of similarities and differences (Cooper, 2013). This study found that employing inquiry-based practices, collectively, allowed students to construct knowledge. Each lesson began with a focus activity in order for students to find connections to their own personal experiences. After a connection was made, the students were able to build upon initial experiences to construct new knowledge. Venn diagrams, tables, and charts were graphic organizers used for data analysis. Additionally, science literacy helped classroom learning make a real world connection.

Moreover, while grounded in Bruner’s constructivist framework, both goals were met in practice: meaningful learning to increase student engagement and using inquiry-based practices for 21st century skills development. The implementation process was crucial to meeting these goals.
Discussion on Implementation Process

In order to attain the desired program goals, a successful implementation process was needed; unfortunately, challenges existed as well. The following elements were part of this process: (a) choosing a curriculum; (b) professional development initially lays a strong foundation; (c) overcoming internal and external obstacles; and (d) post-implementation process.

Choosing a Curriculum

A team approach was used to select FOSS, STCTM, and Lab-Aids as the curricula to support meeting the desired goals. Participants did not share any perspectives contrary to the claimed objectives of each curriculum. Refurbishment of science kits proved to be problematic, but the reasons were not clearly stated.

Moreover, the goal of implementing an inquiry-based curriculum that engaged students in learning science using best practices was successfully achieved, and professional development was a key component.

Professional Development Initially Lays a Strong Foundation

In the initial phase of the transition, PD was effective. It consisted of all the components that were found effective in a study by Thomas et al. (2012): duration; personalized and sustained assistance from an expert; opportunities for active learning; the concreteness, specificity and practicality of the interventions; an observable and measurable impact on student learning; and alignment of interventions with local goals and values (p.444). Despite the fact that teachers at all stages of their careers need ongoing PD (A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012, p. 259), this element of implementation did not last long due to unforeseen obstacles.
Overcoming Internal and External Obstacles

Competing factors to the goals emerged, which interfered with a seamless transition: (a) not all students had access to the curriculum in School K-2, (b) not all parts of the curriculum were inquiry-based, (c) assessments were not aligned with inquiry learning, (d) there was less time to do science, and (e) funding was cut.

Unequal access to inquiry-based curriculum. The study found gaps in the access to the curriculum by all students. Special education teachers were overlooked in the training process and again when curricular supplies were ordered. Consequently, students in those classrooms did not receive instruction through the same curricular program. This inattentive omission was not across all schools, but only at School K-2. At the other schools, special education students were taught at a slower pace, with modifications to fit individual learning needs, using the same curriculum.

Not all parts of the curriculum were inquiry-based. Teachers have freedom or flexibility in how they teach, which is acceptable if the standards are being met. However, it is problematic when teachers continued to use curricula that were not inquiry-based and reverted to the traditional approach. The lack of ability to refurbish science kits became an obstacle to inquiry-based teaching and learning. Because the lessons were not all inquiry-based, students were advancing to the next grade level with little understanding of the inquiry process.

Assessments not aligned with inquiry learning. Although teachers used a range of formative and summative assessments, if they were not from the curriculum then they were not aligned with inquiry-based learning. The district grading policy restricted the use of the better aligned inquiry-based assessments. Teachers had to administer a set number of quizzes and tests each grading quarter; therefore, teachers were using their “teacher-made” assessments. Teachers
knew and understood their tests, thus making their assessments viable alternatives to the inquiry-based curricular assessments if they were to meet policy.

**Less scheduled time to do science.** The teaching time had been reduced for the purpose of increasing teaching time for math and English language arts [ELA]. In ATSD, these subjects took precedence over science. Time reduction was found at the elementary schools; however, Middle School 6-8 was contemplating the same change for the same reason. This assumption was made from Jared’s statement on increasing science time: “The issue with that would also be that it may not be a full year course, but at least if you have more minutes.” In other words, science could become a semester course and more time would be added to math and ELA. Students needed daily time to practice these skills for 21st century citizenship; less scheduled time was counterproductive.

**Funding cuts.** School operations depended on state funding; therefore, the implementation process deteriorated after the funding cuts. ATSD lost over three million dollars due to state funding cuts during the time of state budget crisis. These cuts were crippling, and negatively affected key staff and educational programs. Consequently, school operations continued with fewer teachers, administrators, and programs—namely science, as well as supporting resources that will be subsequently discussed.

**Post-Implementation Process**

Without safeguards in place, ATSD was not prepared when state funding cuts yielded major program interruptions: a lack of ongoing monitoring and turn-key PD. On the other hand, collegial collaboration increased.

**Lack of ongoing monitoring.** Findings in the study showed that the lack of monitoring had negative effects: teachers no longer had a supervisor with science background knowledge,
teachers reverted to non-inquiry instructional approaches, and there was unequal access to the curriculum. Close monitoring or attentiveness in these areas would have minimized these effects.

**Turn-key professional development.** Turn-key PD has not been effective in ATSD. Teachers at all stages of their careers need ongoing PD. *(A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, 2012, p. 259)*. Turn-key training is very brief and is “the teacher's version, here's what I do” (Mary). Therefore, they are training teachers to teach their way. Because of the ineffectiveness of turn-key, teachers began to rely on each other and inadvertently increased collegial collaboration.

**Increased collegial collaboration.** The results of funding cuts were not all negative, since collegial collaboration increased. Teachers relied on each other, as well as on the head teachers and cluster chairs. Seeking support from the head teacher or cluster chair worked better at the Middle School 6-8 than the other schools because the other schools had little to no time in their schedules for meetings. Resourcefully, collaboration was heightened after the budget crisis. Teachers were willingly exchanging knowledge as a result of not being professionally developed so they could maintain instructional expectations.

**Summary of Successes and Shortcomings**

According to Burke (2008), ATSD provided evidence of a transformational move: the need was clearly communicated, staff was involved in the process of choosing the curricula, and professional development was initiated. The goals of ATSD are still aligned with current national science standards; however, work is still needed to strengthen the process to ensure sustainability in acquiring these long-term goals. Therefore, it is important to present the goals of NGSS, to which ATSD goals are aligned, to ensure successful preparation for 21st century citizenship. The goal of NGSS is
to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology.


Many things were successfully accomplished before implementing the program that would provide a blueprint for others.

More importantly, with an understanding that students should engage in practices and not merely learn about them secondhand (Dewey, 2004; Krajcik & Merritt, 2012), meaningful learning was found to be the basis for engagement. Following Bruner’s framework, students constructed knowledge through real world experience with spiraled lessons that were sequenced and structured to acquire content. Not only did ATSD students acquire content through inquiry-based practices, they also developed 21st century skills while doing inquiry. These findings are consistent with studies by other scholars (Barell, 2012; Bell, 2010; Bender, 2012; Jones, 2014; Minner et al., 2010). The overlapping of these skills were also found in a study by Assefa and Gershman (2012). Science offers a rich context for developing many 21st skills (Barell, 2012; Bender, 2012; Hilton, 2010; Jones, 2014; NGSS Lead States, 2013b; NSTA Board of Directors, 2011; Partnership for 21st Century Learning, 2009). These findings have relevance not only to ATSD, but are also of global significance because it is this “blend of these specific skills, content knowledge, expertise and literacies” (P21, 2009) that employees are looking for in a new flat
economy (Greenstein, 2012; Hilton, 2010; Partnership for 21st Century Learning, 2009). While these successes are notable, barriers still existed during and after implementation.

Implementation and post-implementation obstacles were salient, yet surmountable: (a) not all students had access to the curriculum in School K-2, (b) not all parts of the curriculum were inquiry-based, (c) assessments were not aligned with inquiry learning, (d) there was less time to do science, (e) funding cuts were unexpectedly imposed by state government, (f) program monitoring was not ongoing, and (g) turn-key PD proved to be ineffective. These obstacles will be further addressed in the subsequent section on implications for practice. Even though the successes were fewer than the obstacles, teachers remained resilient through collegial collaboration to ensure that students acquired science content, even if the approaches were not in alignment with the rationale.

Implications for Practice

The implications for practice are presented in this section and include five recommendations for suggestions on the obstacles found during the implementation process.

Recommendation 1

This study found that collegial collaboration was heightened as a result of ineffective turn-key PD and by not having a supervisor with a science background to provide support. Taking these two elements into account, ATSD should explore the roles of teacher leaders. Teachers are becoming leaders and experts in their areas of interest who can facilitate professional development and continually research their practice. These roles in teacher leadership are designed to meet personal professional development needs (Rebora, 2015). Some teachers expressed a level of comfort with training others, while others did not. The role of
teacher leaders is changing; therefore teachers should be selected based on their capacity to fill the new roles. Teacher leaders provide a safeguard in the absence of the desired supervisor.

**Recommendation 2**

An assessment team should be created to evaluate assessments and rubrics for 21\textsuperscript{st} century skills and inquiry-based learning. When considering the low 33\% cut score of the state standardized test, a district assessment would be a better gauge of learning and improved teacher practices. Teachers are currently creating rubrics; therefore, this change can be readily researched, adapted, and implemented into practice by creating a committee for evaluating assessments for immediate feedback.

ATSD students take the Partnership for Assessment of Readiness for College and Career (PARCC); however, feedback is not immediate. This district has been doing inquiry for over 10 years and teachers still do not know how well their students are learning, nor how well they are teaching 21\textsuperscript{st} century skills and inquiry-based practices. In addition, the NGSS will be implemented in the 2016-17 school year; therefore, teachers need to have an assessment to gauge learning and teaching. Furthermore, classroom assessment is essential to increase student achievement when “linked to new fewer, clearer, higher standards” by providing teachers with feedback to improve instruction and supply information about student learning ("Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy," 2009, p. 28).

**Recommendation 3**

Monitoring is essential to improve judgments based on informed evaluations; and to evaluate performance not only at the level of students but also at the levels of groups, classes, schools, and states (*A Framework for K-12 Science Education: Practices, Crosscutting...*)
Obstacles were found to be directly correlated to the lack of program monitoring: not all students had access, and teacher flexibility resulted in deviating from inquiry-based teaching, thus impacting learning. It is recommended that a supervisor work closely with a teacher leader to ensure that all teachers have resources and are properly trained on teaching using inquiry-based practices.

**Recommendation 4**

There was less time to do science even though more time was actually needed. The focus should be teaching less content in more depth (*A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, 2012). However, there are still too many concepts to cover in the time scheduled for science, especially considering the preparation time and the teaching schedules at the elementary schools. Two solutions are recommended: an assistant who rotates to help teachers set up and take down the labs and a pilot program where students change classes for social studies and science. In other words, one teacher would teach social studies and science, while the other would teach math and English language arts, or some other combination. A collaborative approach in which teachers teach according their subject expertise has been effective, showing increased learning in all subjects (Nelson & Landel, 2007).

**Recommendation 5**

The final recommendation is professional development on 21st century skills development. All teachers use projects; therefore, implementing project-based learning and problem-based learning would probably be accepted with little resistance. These approaches further deepen the development of 21st century skills (Inel & Balim, 2010; Savery, 2006). These are relevant when considering that NGSS and Science and engineering practices state that teachers need to be prepared on how to ensure that students are meeting performance
expectations (*A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, 2012). Therefore, these can be new practices to enhance pedagogical practices and the learning of STEM.

**Implications for Future Study**

ATSD used the state standardized science test to gauge student learning. This evaluation was problematic as teachers did not have immediate feedback to guide teaching and learning. Higher standards should be set to monitor student achievement, and this process should begin locally. State, national, and international assessments (NAEP, TIMSS, PARCC, PISA) always drive changes in educational policies (NCLB, NSES, NGSS). Rigorous assessments improve student learning and instruction (R. A. S. Duschl, Heidi A; Shouse, Andrew w, 2007; "Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy," 2009). Therefore, ATSD can provide a blueprint on how implementing an in-house assessment that is aligned with inquiry-based practices impacts student science achievement.

**Limitations**

A possible limitation to the study is that in the absence of the special education teacher in School K-2, research at that location was based solely on the perceptions of the head teacher. A special education teacher would have enhanced the findings on the instructional approach used to provide the special needs population with science instruction as a result of not having access to the curriculum. Nevertheless, the results of this study are generalizable. The study clearly revealed how the desired goals were met. In addition, many districts are affected by shortages of money, teaching staff, time, and curricular resources.
References


Gibbs, B. C. (2014). Reconfiguring Bruner: compressing the spiral curriculum: at base, the "spiral curriculum" is the best way to design learning, but we've gone wrong in its implementation. Phi Delta Kappan, 95(7), 41-44.


*Science Educator, 19*(2), 10-21.


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*PARCC COLLEGE- AND CAREER-READY DETERMINATION POLICY IN ENGLISH LANGUAGE ARTS/LITERACY AND MATHEMATICS & POLICY-LEVEL PERFORMANCE LEVEL DESCRIPTORS.*

Retrieved from  

[http://www.parcconline.org/sites/parcc/files/PARCCCCRDPolicyandPLDs_FINAL_0.pdf](http://www.parcconline.org/sites/parcc/files/PARCCCCRDPolicyandPLDs_FINAL_0.pdf)


Appendix A
Areal Township Schools Policy RESEARCH PROJECTS BY STAFF MEMBERS

The Board of Education will cooperate, whenever appropriate and feasible, with organizations and individuals conducting bona fide educational research involving pupils enrolled in the schools of this district.

All educational research by persons other than district employees must be approved in advance by the Board. A written application for approval must state the purpose of the research, the specific ways in which pupils will be involved, the estimated duration of the project, the persons who will conduct the research project and their relevant affiliations, any possible benefits and risks to pupils or to the school district, and methods for maintaining student confidentiality and security.

Approval will be granted only to those projects that will serve the interests of pupils and the educational program; approval will not be granted to projects that will impede or significantly disrupt the instructional program approved by the Board.

Parents or legal guardians will be informed of any educational research project that involves their children and may request the removal of their children from the project.

The Board of Education encourages the participation of teaching staff members in research projects that are soundly designed and professionally conducted.

Teaching staff members may seek funding from local, State, and Federal sources, public and private, for locally conducted research projects. Any research project involving pupils must be approved by the Board; all other research projects involving district personnel, facilities, and/or resources shall be approved by the Superintendent.

An application for approval of a proposed research project must include a detailed description of the project, including:

• The purpose of the research;
• The specific ways in which pupils will be involved and the number of pupils involved;
• The estimated duration of the project; POLICY AREAL TOWNSHIP
• Any possible benefits and risks to pupils or to the school district;
• Methods for maintaining student confidentiality and security;
• The degree to which, if any, the project will interrupt or displace the regular instructional program;
• The period of time that will be devoted to the project;
• The project costs and the source of funding;
• Any background information or literature necessary to understand of the project;
• The means by which the project will be evaluated;
• An assessment of the contribution the project will make to the educational program of this district.

The conduct of research activities must rigorously protect pupils' privacy. The Board must be satisfied that strict standards of anonymity and confidentiality will be observed.
Appendix B

Yolanda F. Boyd
boyd.y@husky.neu.edu

Dr. Nam Repus
Superintendent of Schools
Areal Township Board of Education
700 Earthly Lane
Ideal Suburbia NJ 12345

January 20, 2015

Dear Dr. Repus,

I am a doctoral candidate in Northeastern University. My dissertation proposal is on how our K-8 inquiry based science program prepares all students with 21st century skills for college and career readiness. For this reason, I am writing you to request permission to conduct my research in Areal Township. I am hopeful that study proves to be invaluable to our district twofold: a better understanding of how the curriculum is meeting the academic needs of all students and knowing how well it is aligned with the new science standards (NGSS) that purposed to make certain that all students achieve science content knowledge and skills for college and career readiness.

My research requires the use of multiple sources of data: science standardized test scores for grades 4 and 8, demographics, focus groups and interviews with administrators as well as teachers. Attached is the IRB approval to ensure that no harm will be done to the participants. If you have any questions, or need further information, please do not hesitate to contact me or my advisor, Dr. Kelly Conn. Her email address is k.conn@neu.edu.

Thank you in advance for assisting me in this important endeavor, as a life-long learner.

Yolanda F. Boyd
7th Grade Science Teacher
Enc. Dissertation proposal
IRB Approval
Appendix C

Dr. Nam Repus
Superintendent of Schools
Areal Township Board of Education
700 Earthly Lane
Ideal Suburbia NJ  12345

Northeastern University IRB granted approval for my dissertation proposal on how our K-8 inquiry based science program prepares all students with 21st century skills for college and career readiness. Attached is the IRB approval, as well as letters that will be emailed to recruit participants. It is a busy time, and I will be respectful and thankful for whatever time is granted.

As we discussed, your assistance is needed as a gateway for me to begin research. With that being said, could you please email the staff at Young, FWS, and BTMS in order to inform them of the study and the value that it will bring to our district?

I am hopeful that study proves to be invaluable to our district twofold: a better understanding of how the curriculum is meeting the academic needs of all students and knowing how well it is aligned with the new science standards (NGSS) that purposed to make certain that all students achieve science content knowledge and skills for college and career readiness.

My research requires the use of multiple sources of data: science standardized test scores for grades 4 and 8, demographics, focus groups and interviews with administrators as well as teachers. As you are aware, the IRB approval ensures that no harm will be done to the participants. If you have any questions, or need further information, please do not hesitate to contact me or my advisor, Dr. Kelly Conn. Her email address is k.conn@neu.edu.

Thank you in advance for assisting me in this important endeavor, as a life-long learner.

Yolanda F. Boyd
Appendix D

Recruitment letter to All Elementary Teachers and Middle School Science Teachers

Dear Teacher of Science:

As you are aware, Dr. Repus sent an email stating that I will be contacting staff members to participate in my study on how our district is preparing all students with science content and 21st century skills using an inquiry based curriculum. The aim of the study is to understand how the program is meeting the needs of all students for 21st century citizenship. Therefore, you have been chosen to participate in the study by granting me an interview that will last for 30-60 minutes.

You were selected because you teach science. In view of the fact that this study is to formatively assess our current inquiry based science program, science teachers would be able to better assist with the goals of the study.

Your participation is confidential and pseudonyms will be used in the report for participants as well as the school names. Your participation is voluntary; however, very much invaluable to me, thus the evaluation of the program. I can meet with you at any place of your choosing, even at your home.

Please RSVP YES or NO in the subject line by April 30. You will receive a follow-up response from me regarding further details for participation.

I greatly appreciate your willingness to help me with this endeavor.

Yolanda F. Boyd
Appendix E
Principal Administrator Recruitment Letter

Dear Administrator,

As you are aware, Dr. Repus sent an email stating that I will be contacting staff members to participate in my study on how our district is preparing all students with science content and 21st century skills by using an inquiry based curriculum. The aim of the study is to understand how the program is meeting the needs of all students. Therefore, you have been chosen to participate in the study by granting me an interview that will last for 30-60 minutes.

The reason why you were selected is because you have been in your position during the transition from the traditional approach of teaching science to the inquiry based approach and when the emphasis on 21st century skills became a focus of lesson planning.

Your participation is confidential and pseudonyms will be used in the report for participants as well as the school names. You will also be given the opportunity to review the transcript of our interview before it gets included. If you do not agree with the transcription, it will not be used. Your participation is voluntary; however, very much invaluable to me, thus the evaluation of the program.

Lastly, I need your help to identify veteran teachers, special education teachers, and new teachers (less than four years) for me to contact for recruitment into the study. Also, I am requesting release time for them to participate. This time could be during teacher team, professional development, or any mutual time that you allot. The time needed for the teacher interviews and focus groups is 30-60 minutes as well.

I greatly appreciate your willingness to help me with this endeavor.

Yolanda F. Boyd
Appendix F

Former Superintendent - Central Administrator Recruitment Letter

Dear Administrator,

I am a doctoral candidate in Northeastern University. My dissertation proposal is on how our K-8 inquiry based science program prepares all students with 21st century skills for college and career readiness. I am contacting you to participate in my research. The aim of the study is to understand how the program is meeting the needs of all students and the goals of the district for the purpose of preparing students for successful 21st century citizenship.

You were selected to be interviewed because you initiated the change from a traditional approach of teaching science in grades K-8 to an inquiry based approach. The interview will last for 30-60 minutes.

Your participation is confidential and pseudonyms will be used in the report for participants as well as the school names. You will also be given the opportunity to review the transcript of our interview before it gets included. If you do not agree with the transcription, it will not be used.

Your participation is voluntary; however, very much invaluable to me, thus the evaluation of the program.

I greatly appreciate your willingness to help me with this endeavor.

Yolanda F. Boyd
Appendix G
Vice Principal - Administrator Recruitment Letter

Dear Administrator,

As you are aware, Dr. Repus sent an email stating that I will be contacting staff members to participate in my study on how our district is preparing all students with science content and 21st century skills by using an inquiry based curriculum. The aim of the study is to understand how the program is meeting the needs of all students. Therefore, you have been chosen to participate in the study by granting me an interview that will last for 30-60 minutes.

The reason why you were selected is because you started in your position after the implementation of the inquiry based program and since the emphasis on 21st century skills became focus of lesson planning.

Your participation is confidential and pseudonyms will be used in the report for participants as well as the school names. You will also be given the opportunity to review my transcript of our interview before it gets included. If you do not agree with the transcription, it will not be used. Your participation is voluntary; however, very much invaluable to me, thus the evaluation of the program.

I greatly appreciate your willingness to help me with this endeavor.

Yolanda Boyd
Appendix H

Northeastern University, Department of Education
Name of Investigators: Dr. Kelly Conn, Yolanda F. Boyd
Title of Project: Inquiry Based Science: Preparing Human Capital for 21st Century and Beyond

CONSENT TO SERVE AS A PARTICIPANT IN RESEARCH

I consent to serve in the research by Yolanda F. Boyd entitled: Inquiry Based Science: Preparing Human Capital for the 21st Century and Beyond.

The nature and general purpose of the research is to formatively assess the inquiry based science program and to understand its integration of 21st century skills. My participation is viable to understanding how the program is meeting the needs of all students and how to improve the program, if needed. I am being asked because of my role as a science teacher or an administrator.

I will be interviewed in my own home or at a time and place that is convenient for me. The interview will take about one hour. After the study results have been compiled, I will be asked to participate in a focus group to discuss the findings.

I understand that my identity will be kept confidential. No identifying information will be shared with anyone, and there are no foreseeable risks.

My participation is voluntary, I may refuse to answer any questions, and I may withdraw from the study at any time.

If I have any questions about this study, I will contact Yolanda Boyd (boyd.y@husky.neu.edu), the person mainly responsible for the research. I can also contact Dr. Kelly Conn (k.conn@neu.edu), the Principal Investigator.

If you have any questions about your rights in this research, you may contact Nan C. Regina, Director, Human Subject Research Protection, 960 Renaissance Park, Northeastern University, Boston, MA 02115. Tel: 617.373.4588, Email: n.regina@neu.edu. You may call anonymously if you wish.

Participant’s Signature

Date:

Printed name of person above

Signature of person who explained the study to the participant above and obtained consent

Date:

Printed name of person above

To be retained by the principal investigator
Appendix I

NOTIFICATION OF IRB ACTION

Date: May 13, 2015
IRB #: CPS15-04-12
Principal Investigator(s): Kelly Conn
Yolanda Boyd
Department: Doctor of Education Program
College of Professional Studies
Address: 20 Belvidere
Northeastern University
Title of Project: Inquiry Based Science: Preparing Human Capital for 21st Century and Beyond
Participating Sites: Township School District approval in file
DHHS Review Category: Expedited #6, #7
Informed Consents: One (1) signed consent form
Monitoring Interval: 12 months

APPROVAL EXPIRATION DATE: MAY 12, 2016

Investigator’s Responsibilities:
1. The informed consent form bearing the IRB approval stamp must be used when recruiting participants into the study.
2. The investigator must notify IRB immediately of unexpected adverse reactions, or new information that may alter our perception of the benefit-risk ratio.
3. Study procedures and files are subject to audit any time.
4. Any modifications of the protocol or the informed consent as the study progresses must be reviewed and approved by this committee prior to being instituted.
5. Continuing Review Approval for the proposal should be requested at least one month prior to the expiration date above.
6. This approval applies to the protection of human subjects only. It does not apply to any other university approvals that may be necessary.

C. Randall Colvin, Ph.D., Chair
Northeastern University Institutional Review Board

Nan C. Regina, Director
Human Subject Research Protection

Northeastern University FWA #4630
Appendix J
Interview Protocol
Topics/Questions to Guide Interviews
Research Questions: (to ensure that interview informs research questions)

Central Question: Based on teacher perceptions, how does the implementation of an inquiry-based program within the Areal Township School support the acquisition of science content knowledge and the development of 21st century skills?

a. Why did individuals decide to transition to an inquiry-based program and how was the need met?

b. How does the inquiry-based program in Areal Township promote accessing scientific content knowledge?

c. How does the inquiry-based program in Areal Township promote the development of 21st century skills?


Interviews are particularly useful for getting the story behind a participant’s experiences. The interviewer can pursue in-depth information around a topic. Interviews may be useful as follow-up to certain respondents to questionnaires, e.g., to further investigate their responses. Usually open-ended questions are asked during interviews.

Before you start to design your interview questions and process, clearly articulate to yourself what problem or need is to be addressed using the information to be gathered by the interviews. This helps you keep clear focus on the intent of each question.

Preparation for Interview
1. Choose a setting with little distraction. Avoid loud lights or noises, ensure the interviewee is comfortable (you might ask them if they are), etc. Often, they may feel more comfortable at their own places of work or homes.
2. Explain the purpose of the interview.
3. Address terms of confidentiality. Note any terms of confidentiality. (Be careful here: Rarely can you absolutely promise anything. Courts may get access to information, in certain circumstances.) Explain who will get access to their answers and how their answers will be analyzed. If their comments are to be used as quotes, get their written permission to do so. See getting informed consent.
4. Explain the format of the interview. Explain the type of interview you are conducting and its nature. If you want them to ask questions, specify if they’re to do so as they have them or wait until the end of the interview.
5. Indicate how long the interview usually takes.
6. Tell them how to get in touch with you later if they want to.
7. Ask them if they have any questions before you both get started with the interview.
8. Don’t count on your memory to recall their answers. Ask for permission to record the interview or bring along someone to take notes.

Type of Interview for this study
General interview guide approach - the guide approach is intended to ensure that the same general areas of information are collected from each interviewee; this provides more focus than the conversational approach, but still allows a degree of freedom and adaptability in getting information from the interviewee.

Types of Topics in Questions
Patton notes six kinds of questions. One can ask questions about:

1. Behavior - about what a person has done or is doing
2. Opinions/values - about what a person thinks about a topic
3. Feelings - note that respondents sometimes respond with "I think..." so be careful to note that you're looking for feelings
4. Knowledge - to get facts about a topic
5. Sensory - about what people have seen, touched, heard, tasted or smelled
6. Background/demographics - standard background questions, such as age, education, etc.

Note that the above questions can be asked in terms of past, present or future.

Sequence of Questions
1. Get the respondents involved in the interview as soon as possible.
2. Before asking about controversial matters (such as feelings and conclusions), first ask about some facts. With this approach, respondents can more easily engage in the interview before warming up to more personal matters.
3. Intersperse fact-based questions throughout the interview to avoid long lists of fact-based questions, which tends to leave respondents disengaged.
4. Ask questions about the present before questions about the past or future. It's usually easier for them to talk about the present and then work into the past or future.
5. The last questions might be to allow respondents to provide any other information they prefer to add and their impressions of the interview.

Wording of Questions
1. Wording should be open-ended. Respondents should be able to choose their own terms when answering questions.
2. Questions should be as neutral as possible. Avoid wording that might influence answers, e.g., evocative, judgmental wording.
3. Questions should be asked one at a time.
4. Questions should be worded clearly. This includes knowing any terms particular to the program or the respondents' culture.
5. Be careful asking "why" questions. This type of question infers a cause-effect relationship that may not truly exist. These questions may also cause respondents to feel defensive, e.g., that they have to justify their response, which may inhibit their responses to this and future questions.

Conducting Interview
1. Occasionally verify the tape recorder (if used) is working.
2. Ask one question at a time.
3. Attempt to remain as neutral as possible. That is, don't show strong emotional reactions to their responses. Patton suggests to act as if "you've heard it all before."
4. Encourage responses with occasional nods of the head, "uh huh's, etc.
5. Be careful about the appearance when note taking. That is, if you jump to take a note, it may appear as if you're surprised or very pleased about an answer, which may influence answers to future questions.
6. Provide transition between major topics, e.g., "we've been talking about (some topic) and now I'd like to move on to (another topic)."
7. Don't lose control of the interview. This can occur when respondents stray to another topic, take so long to answer a question that times begins to run out, or even begin asking questions to the interviewer.

Immediately After Interview
1. Verify if the tape recorder, if used, worked throughout the interview.
2. Make any notes on your written notes, e.g., to clarify any scratchings, ensure pages are numbered, fill out any notes that don't make sense, etc.
3. Write down any observations made during the interview. For example, where did the interview occur and when, was the respondent particularly nervous at any time? Were there any surprises during the interview? Did the tape recorder break?
### Alignment of Research questions with Interview Questions and Participants

**Study Sub Question 1: Why did individuals decide to transition to an inquiry based program and how was the need met?**

<table>
<thead>
<tr>
<th>Interview Questions for Participants</th>
<th>Central Administrators</th>
<th>School Administrator</th>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Who decided on the change and why?</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. How did you decide on which textbooks or inquiry based program would meet the goals for the transition?</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Describe the transition process</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. What changes do you perceive is needed to take place to be in alignment with NGSS?</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>6. How do STEM and 21st century skills fit in your goals or vision for the district?</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7. How will teachers be prepared to meet NGSS?</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>8. How do you feel the curriculum meets the needs of all students, including those with special needs?</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>9. How did you feel about changing to the new curriculum?</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>10. Describe the transition in terms of support for teachers – Probes: PD training, teaching strategies</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>11. Who is the go to person for science curriculum challenges in your building or district?</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>12. How do teachers play a role in decisions on their professional development that is provided in your district?</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Study Sub Question 2  

How does the inquiry based program in Areal Township promote accessing scientific content knowledge?

<table>
<thead>
<tr>
<th>Interview Questions For Participants</th>
<th>Central Administrators</th>
<th>School Administrator</th>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How is science content knowledge assessed in Areal Township Schools and what is the trend of these assessments over the last 11 years? Probe for Written, oral, projects?</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2. Share your observation of the engagement of students doing inquiry</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3. Tell me about the teaching schedule</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>4. How often do teachers get to share ideas and problem solve about the curriculum and teaching strategies?</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5. Do you have to strictly follow the curriculum or can you create your own lessons? Do you have examples of these lessons?</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>6. Describe your classroom environment.</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7. How are your teachers implementing STEM into lessons?</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>8. What are the perceptions on the acquisition of science content?</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>9. What does the inquiry based science program look like in Areal Township Schools and in what ways does it align with the NGSS?</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>10. When observing a science lesson, what do you look for in terms of inquiry based instruction and 21st century lessons?</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>11. Did you have to change your teaching strategies to teaching inquiry? If so, how?</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>12. What do you perceived to be the greatest part of the curriculum that has positive impact on learning content? And the weakest?</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Research Sub-Question 3

How does the inquiry based program in Areal Township promote the development of 21st century skills?

<table>
<thead>
<tr>
<th>Interview Questions For Participants</th>
<th>Central Administrators</th>
<th>School Administrator</th>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are the participants perception on the acquisition of 21st century skills</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2. What are 21st century skills and what is the districts goal for these skills</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3. Since 21st century skills is a goal for the district, who provides the professional development for teachers and how often?</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4. How do teachers play a role in decisions on their professional development that is provide in your district?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. What is your perception on the practice and obstacles of imparting 21st century skills in the classroom</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
ASKING QUESTIONS

Asking Questions that Yield Powerful Information

by Richard A. Krueger

• Use open-ended questions
  "What did you think of the program?"
  "Where do you get new information?"
  "What do you like best about the proposed program?"
  Be cautious of phrases such as "how satisfied" or "to what extent"

• Avoid dichotomous questions
  These questions can be answered with a "yes" or "no"

• Why? is rarely asked
  Instead ask about attributes and/or influences. Attributes are characteristics or features of the topic. Influences are things that prompt or cause action.

• Use "think back" questions.
  Take people back to an experience and not forward to the future

• Use different types of questions
  Identify potential questions
  Five Types of Questions
  1. Opening Question (round robin)
  2. Introductory Question
  3. Transition Questions
  4. Key Questions
  5. Ending Questions

• Use questions that get participants involved
  Use reflection, examples, choices, rating scales, drawings, etc.

• Focus the questions
  Sequence that goes from general to specific

• Be cautious of serendipitous questions
  Save for the end of the discussion

Ending Questions

• All things considered question
  This question asks participants to reflect on the entire discussion and then offer their positions or opinions on topics of central importance to the researchers.

  Examples:
  "Suppose that you had one minute to talk to the governor on merit pay, the topic of today's discussion. What would you say?"
  or
  "Of all the things we discussed, what to you is the most important?"

• Summary question
  After the brief oral summary the question asked is:
  "Is this an adequate summary?"

• Final question
  The moderator reviews the purpose of the study and then asks the participants:
  "Have we missed anything?"
**Generic Questions**

Example #1

1. How have you been involved in _____?
2. Think back over all the years that you've participated and tell us your fondest memory. (The most enjoyable memory.)
3. Think back over the past year of the things that (name of organization) did. What went particularly well?
4. What needs improvement?
5. If you were inviting a friend to participate in (name of organization), what would you say in the invitation?
6. Suppose that you were in charge and could make one change that would make the program better. What would you do?
7. What can each one of us do to make the program better?

Example #2

Here is a sample set of questions that could be used for many consumer products. Modify and adjust the questions as needed. The questions might be applicable to such categories as: soap, breakfast cereal, fast food restaurants, automobiles, golf clubs, fishing equipment, cosmetics, deodorant or a variety of other products. These questions could be used for practice focus groups to allow moderators a chance to lead the discussion, for assistants to take field notes and provide oral summaries. You may want to have five to seven people in each focus group and then sitting slightly back from the table could be a number of assistant moderators.

- How and when do you use XXXX?
- Tell me about positive experiences you've had with XXXX?
- Tell me about disappointments you’ve had with XXXX?
- Who or what influences your decision to purchase a particular type of XXXX?
- When you decide to purchase XXXX, what do you look for? Take a piece of paper and jot down three things that are important to you when you purchase XXXX?
- Let's list these on the flip chart. If you had to pick only one factor that was most important to you, what would it be? You can pick something that you mentioned or something that was said by others.
- Have you ever changed brands or types of XXXX? What brought about the change?
- Of all the things we've talked about, what is most important to you?
Figure A.1. School K-2 Hannah’s Student Science Center
Figure A.2. School K-2 Hannah Class wildflower garden that is in the school’s courtyard
<table>
<thead>
<tr>
<th>Date</th>
<th>Height</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/24/15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/29/15</td>
<td>1 cent</td>
<td></td>
</tr>
<tr>
<td>May 4th</td>
<td>2 cent</td>
<td></td>
</tr>
<tr>
<td>May 7th</td>
<td>4 cent</td>
<td></td>
</tr>
<tr>
<td>May 12th</td>
<td>6 cent</td>
<td></td>
</tr>
<tr>
<td>May 14th</td>
<td>7 cent</td>
<td></td>
</tr>
<tr>
<td>May 15th</td>
<td>8 cent</td>
<td></td>
</tr>
<tr>
<td>May 18th</td>
<td>9 cent</td>
<td></td>
</tr>
<tr>
<td>May 20th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 3rd</td>
<td>8 cent</td>
<td></td>
</tr>
</tbody>
</table>
Alexander Calder: The Mobile Man

Do you know what you want to be when you grow up? Some people do. Alexander Calder was one of those people. He was born in 1898, and from the time he was a boy, he knew he wanted to be an artist.

Alexander, or Sandy as his family always liked to call him, was very young when he first started to make things. He was about five years old, and he used wire and string to make pictures of people and animals. When he was eight, he started making jewelry. Using beads and copper wire, he would make beautiful pieces for his sister Peggy’s room.

Fast forward to Sandy as a boy and his family moved to New York City. He was always busy making things. He loved making mobiles out of paper, wire, and other materials that could move through the air and create beautiful sculptures that could hang from the ceiling.

Sandy continued to work on his art. He grew to love making mobiles with colors like red, blue, and green. He liked to use simple shapes like rectangles and circles. He wondered if he could figure out a way to make these shapes move. So he invented mobiles, which could hang in the air and “dance with the joy of life and movement.”

His art had an impact on his community. People all over the world were enjoying his new form of art.

When you make your mobiles, you can use any shapes or materials. Sandy Calder used whatever he had around him to create his art. He was a true artist and a true innovator.
Figure A.5. Student Journal Page. Planning and carrying out investigations-critical thinking-communication-collaboration-problem solving.
Figure A.6. Story of the Sand. Using mathematical computational thinking-critical thinking-communication-problem solving.
Figure A.7. Constructing explanations-critical thinking-communication
Figure A.8. School K-2 Hannah’s student’s journal
Figure A.9. School K-2 Dated entry of a student’s science journal showing the “fulcrum”
Developing and using models-critical thinking
Figure A.10. First Grade Curriculum (traditional approach)
Figure A.11. Analyzing and interpreting data-critical thinking-communication-problem solving
Figure A.12. Student Project
Appendix M
Middle School 6-8

Figure A.13. Class Library - 8th Grade:

Figure A.14. Student Notebook
Appendix N

Figure A.15. Grading Policy at the Middle School 6-8;
8th Grade Project

End of Year Science Project

Children’s Story Book

| Energy, Motion and Light | Human Body | Space |

Objective:
~Write and illustrate a children’s book with a science theme that was covered this year.

Requirements:
~You may work by **yourself or with 3 other people**.
~Choose an audience between 2nd and 6th graders.
~Your story must have a **concept that we covered in class** (flip through your notebook for a look at everything we covered this year).
~Your story must be between 16-20 pages in length (including inside and outside cover).
~Your story must be **typewritten** (unless otherwise approved by the teacher).
~Your story must have **color illustrations** (hand-drawn, painted, clip art, photos, collage, etc).
~Keep your story **simple and clear**- remember who your audience is.
~You can **teach a concept** and still include **humor** or a **fictional story**.

Suggested Timeline:
~Story idea sheet- first 2 weeks of May
~Rough draft – by the end of May
~Final book- finished no later than June 6

Grading:
This project is worth a **TEST** grade in **Science** based on the following:

<table>
<thead>
<tr>
<th></th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing style/content</td>
<td>10</td>
</tr>
<tr>
<td>Neatness/typed</td>
<td>10</td>
</tr>
<tr>
<td>Grammar/spelling</td>
<td>10</td>
</tr>
<tr>
<td>Age appropriateness of concept</td>
<td>10</td>
</tr>
<tr>
<td>Science content</td>
<td>30</td>
</tr>
<tr>
<td>Story clear/understandable</td>
<td>20</td>
</tr>
<tr>
<td>Appropriate illustrations</td>
<td>10</td>
</tr>
</tbody>
</table>

**Total Points** 100
End of Year Science Project
The ABC’s of Science

| Energy, Motion and Light | Human Body | Space |

Objective:
~ Create an ABC book to demonstrate an in-depth knowledge of the concepts we have learned in science this year.

Requirements:
~ You may work by yourself or with 3 other people.
~ For each letter of the alphabet, give a science concept that you have learned this year that starts with that letter.
~ Each letter should be on a separate page organized and bound together.
~ Include a cover page with the title “The ABC’s of Science” and your name(s).
~ Be creative! Each page should be colorful and represent something that we studied this year!
~ Each page must include the following:
  ~ The letter represented in a large, colorful and creative manner.
  ~ The concept that the letter represents and its definition.
  ~ A description of how the concept connects to what we learned in class.
  ~ An illustration of the concept.

Suggested timeline:
~ Letter outline: First two weeks of May
~ Pages A-L: Last two weeks of May
~ Pages M-Z: finished no later than June 6

Grading:
This project is worth a TEST grade in Science based on the following:

<table>
<thead>
<tr>
<th>Item</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each letter of the alphabet is represented</td>
<td>10</td>
</tr>
<tr>
<td>Each page includes a colorful/attractive illustration of the concept</td>
<td>20</td>
</tr>
<tr>
<td>Each letter includes a definition of the concept</td>
<td>20</td>
</tr>
<tr>
<td>Each letter includes a description of how it connects to class</td>
<td>20</td>
</tr>
<tr>
<td>Concepts are from all units studied this year/shows an understanding</td>
<td>20</td>
</tr>
<tr>
<td>Spelling and grammar</td>
<td>10</td>
</tr>
<tr>
<td>Total Points</td>
<td>100</td>
</tr>
</tbody>
</table>
End of Year Science Project
Science Superstar Video

Energy, Motion and Light ---- Human Body ---- Space

Objective:
~ Demonstrate your expertise on a topic that was covered this year by performing a science skit in a Bill Nye-style video.

Requirements:
~ You may work by yourself or with 3 other people.
~ You will perform live OR you may choose to take video of your skit.
~ Your skit should include:
  ~ A complete or thorough introduction of your topic.
  ~ Science vocabulary that is used correctly.
  ~ A visual representation of your topic, either by doing a demonstration, an experiment, or by using some other visual aid.
~ Be creative, original and as entertaining as possible. You may rewrite a song with appropriate science lyrics, wear costumes and let your imagination run wild.

Suggested outline:
A. Topic Introduction:
   1. Theories/Concepts: What theories or concepts are associated with your topic?
   2. Formulas: Any formulas go with your topic?
   3. Key Vocabulary: What words does the audience need to know and understand in relation to this topic?
   4. Labs/Activities: What did we do in class to show this topic?
B. Creative Ways to Present Information:
   1. Do you have a great lead? How will you grab the audience?
   2. How will you transition between scenes?
   3. Who will narrate each scene?
   4. How will you make each scene interesting and amusing?
   5. How is this topic useful in everyday life? What examples can you provide?
C. Demonstrations/Visuas/Experiments
   1. How will you show the audience what the concepts are? What lab or activity can you do?
   2. What charts, graphs, posters, flowcharts, pictures, or diagrams can we use to give the audience a better picture of what you are talking about?
Grading:
This project is worth a TEST grade in Science based on the following:

**Topic Introduction**  40
*Presentation includes relevant theories and formulas
*Uses science vocabulary correctly
*Includes a review of how the concept was taught in class
*Explains how the concept is important to everyday life

**Demonstrations/Visuels/Experiments**  30
*Includes at least one demo or experiment
*Includes at least one visual aid (charts, graphs, diagram, flowchart etc.)

**Creativity and Preparedness**  30
*Used clear, loud voices. Evidence that the skit is well planned.
*Skit was creative and amusing, while covering the key concepts

**Total Points**  100
End of Year Science Project

Science-Themed Board Game

| Energy, Motion and Light | Human Body | Space |

**Objective:**
~Create an entertaining science board game using one of the units that was covered this year.

**Requirements:**
~You may work by **yourself or with 3 other people**
~Choose an audience between 6th and 8th graders.
~Your game must have a **concept that we covered in class**
~Your game must have a **creative name** and **at least 4 game pieces** (cannot use ones directly from another game).
~Your game must have **clear directions!**
~Your game board must have **at least 25 colorful spaces** and is related to your theme.
~Your game must include **at least 25 correct, creative, and challenging question and/or activity cards.**
~Play your game to make sure it is entertaining!!

**Suggested Timeline:**
~Pick a theme and layout- first 2 weeks of May
~Finish game board and rough draft of questions – by the end of May
~Final game- finished no later than June 6

**Grading:**
This project is worth a **TEST** grade in **Science** based on the following:

<table>
<thead>
<tr>
<th>Category</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creative name</td>
<td>10</td>
</tr>
<tr>
<td>At least 4 game pieces</td>
<td>10</td>
</tr>
<tr>
<td>Clear Directions</td>
<td>10</td>
</tr>
<tr>
<td>At least 25 colorful spaces</td>
<td>25</td>
</tr>
<tr>
<td>At least 25 question and/or activity cards</td>
<td>25</td>
</tr>
<tr>
<td>Grammar/spelling</td>
<td>10</td>
</tr>
<tr>
<td>Neatness and Creativity</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total Points</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Appendix P

Middle School Projects
Figure A.16. End of year 8th project
Figure A.17. End of year 8th grade project
Figure A.18. End of year 8th grade project
Figure A.19. End of Year 8th grade project (story book)
Figure A.20. End of year 6th grade project
Figure A.21. End of year 6th grade project
Figure A.22. End of year 6th grade project
Figure A.23. 8th grade Analyzing and interpreting data-critical thinking-communication-problem solving.
Lab Reflection Questions  
Inquiry 2.1: Building a Battery

1. The goal of this lesson was to build a battery. Did you succeed? Support your answer with evidence.  
   We succeeded in our experiment when we pushed on the wires, the light lit up.

2. Describe what makes up a battery. Include a sketch of your setup.

   ![Sketch of battery setup]

3. What do you conclude from your observations of the zinc-copper strips you placed in the copper sulfate solution? The strips react with the wire and it causes it to light up.

4. What happened to your light bulb after you removed the assembly from the solution? How would you explain what happened to someone else? After removing the light bulb from the solution, if we push on the tape the light still lit up.

5. In this activity, you probably noticed that the bulb was not very bright. What could you do to make the bulb grow more brightly? We could try to leave the light bulb in the solution longer.

Figure A.24. Spiral curriculum example 8th grade