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Case Study: Exploring the Implementation of an Integrated STEM Curriculum Program in Elementary First Grade Classes

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Abstract

This study explored the implementation of Project Lead The Way (PLTW) integrated science, technology, engineering, and mathematics (STEM) curriculum in four first grade classrooms. Data was collected from four teachers and two media specialists via interviews and student PLTW Light and Sound unit assessment scores. A self-efficacy survey was administered to all first grade teachers in the studied district to measure teacher beliefs about their ability to teach science. Teacher responses indicated that teachers were relatively confident implementing science curriculum. Interviews, however, revealed that teachers required more training designed to increase teacher science background knowledge to properly teach an integrated science unit. Although there were issues with implementation involving materials and scheduling, the benefits for student learning through the PLTW curriculum were substantial. The most important finding of this study was the fact that integrated STEM curriculum, such as PLTW, has the innate ability to reach and challenge students at all levels, from gifted learners to at-risk students. Using the hands-on approach, students can experiment and find solutions. Students, through the process, develop an understanding of the concept and can apply their learning. However, to implement integrated STEM effectively, teachers need support from their administrators and dedicated training in the PLTW program.

Keywords: early elementary education, integrated STEM education, Project Lead The Way curriculum

Dedication

I would like to dedicate this dissertation to all of those out there with a dream. I have wanted to have my doctorate degree since I was attending classes for my undergraduate degree, and I have finally achieved that goal. It seemed like a really big dream, and I wondered often if it was too big, but thanks to my family and my teachers, I achieved it.

Acknowledgements

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Chapter 1: Introduction to the Problem

Science, technology, engineering, and mathematics (STEM) is a career field that is expanding at a rapid rate and is an area where there is a growing shortage of workers in the United States (Desilver, 2017; Noonan, 2017). Unfortunately, the number of students who are pursuing careers in STEM fields is lagging behind the rate of growth (Langdon, McKittrick, Beede, Khan, & Doms, 2011). The United States must rely on other countries to provide the needed workers to fill the available STEM jobs (Varas, 2016). Students are required to pursue careers in STEM areas and eventually fill STEM career positions. To accomplish this, interest in STEM subjects needs to be established during students' elementary years and continue through graduation.

To boost enrollment and interest in STEM fields, STEM education should begin in the early elementary years (DeJarnette, 2012; Yoon, Lucietto, Capobianco, Dyehouse, & Diefes-Dux, 2014). During these years, students can build the foundational knowledge they need to be successful with STEM in the future, as well as develop their interest in STEM fields for future study (Aldemir & Kermani, 2016). Building the foundation at an early age will boost not only the confidence of the students, but also their interest in continuing to take classes in STEM fields.

To implement STEM education effectively, teachers in lower elementary grades need to have an in-depth knowledge of STEM subjects (Moore & Smith, 2014). Teachers in these grades have some training in STEM subjects, however, it is not as in-depth as they need to competently teach science and math (Bissaker, 2014; Epstein & Miller, 2011; Nadelson, Seifert, Moll, & Coats, 2012). Engineering is not a typical curriculum area for elementary standards; therefore, this subject is not often included in preservice teacher training. Technology is included, however, the focus is on how the preservice teacher can utilize technology for teaching, not how to instruct students in technology education. Science and math have had a more prominent focus than engineering and technology, however, often the training is not rigorous enough to develop a foundation for teaching (Epstein & Miller, 2011). Teachers also need training to learn how to effectively integrate STEM subjects into the curriculum (Moore & Smith, 2014).

There are very few programs for integrated STEM curriculum at the elementary level. In the *Rising Above the Gathering Storm* report, the National Academy of Sciences named Project Lead The Way (PLTW) as an example of a curriculum built on excellent standards (National Academy of Engineering and National Research Council, 2009). PLTW was the only curriculum mentioned in the report. Other examples of STEM curriculum are Rokenbok Education, which provides home and school curriculum with kits available for purchase (Kid Spark Education, 2015); Iridescent, a curriculum for parents to use at home that is aimed at girls and underrepresented groups (Iridescent, 2017; and the Creative Core Curriculum program, which includes STEM lessons created by the Center for Mathematics, Science, and Technology at Illinois State University (Illinois State University, 2017).

PLTW was chosen as the curriculum to study, as it is a fully integrated curriculum that is research-based. The program was developed for teachers to implement while also providing teachers with initial training and ongoing support. The training of teachers in teaching STEM subjects using PLTW curriculum as well as teachers' perceptions of the effect on student learning are the areas being explored in the present study.

Background of the Problem

Many careers in the STEM field are growing at a rate faster than qualified American workers are found to fill the jobs (Schmidt & Fulton, 2016). There are not enough students pursuing STEM careers at the collegiate level, however, the problem begins much sooner than this (DeJarnette, 2012; Moore, Tank, Siverling, & Mathis, 2014; Sadler, Sonnert, Hazari, & Tai, 2012; Schmidt & Fulton, 2016; Yoon et al., 2014). It is important to interest young students in elementary school in science, technology, engineering, and mathematics as subjects (Kermani & Aldemir, 2015) and careers (Kurz, Yoder, & Zu, 2015).

Early interest in STEM careers is an indicator that interest will continue as a student advances in school (Sadler et al., 2012). Students who showed an interest in a STEM career at the start of high school were nine times more likely to continue to have an interest in a STEM career at the end of high school (Sadler et al., 2012). Integrated STEM education is the key to nurturing the interest that already exists and it is important to develop that interest through elementary and secondary schools (Sanders, 2009). Exposure to STEM subjects needs to begin before the third grade as interest in a STEM career begins to decline as early as the fourth and fifth grades (Kurz et al., 2015; Yoon et al., 2014).

Teachers need more training not only in how to teach STEM subjects effectively, but also to develop their knowledge level in each of the subjects (DeJarnette, 2012; Schmidt & Fulton, 2016). When teachers lack confidence or content knowledge, they are unlikely to implement a subject such as science or mathematics (Yoon et al., 2014). Integrated STEM curriculum is linked to inquiry-based learning and teachers need a strong level of knowledge of both the subject and pedagogy of inquiry-learning to successfully implement the integrated STEM curriculum (Ramnarain, 2014). There is a lack of guidance for teachers on how to begin this shift to integrating STEM and gaining STEM-related content knowledge (Guzey, Moore, & Harwell, 2016). Teachers are more willing to integrate STEM curriculum when they see a model of how it can be done (Nadelson et al., 2013).

Currently, there are very few models of effective STEM integration curriculum at the elementary level. The United States federal government has been working in the last decade on developing frameworks and standards to use for curriculum development (National Research Council, 2013; Quinn, Schweingruber, & Keller, 2012). The Next Generation Science Standards (NGSS) have been developed to integrate engineering design at the elementary level (National Research Council, 2013). However, NGSS is not curriculum and that is what is needed.

Statement of the Problem

Current federal government initiatives in science education do not address the need for teacher training in STEM strategies at the elementary level (Epstein & Miller, 2011). The focus of government initiatives has been on secondary and postsecondary students and their interest in STEM classes and careers (DeJarnette, 2012). Additionally, further research is required around teacher perceptions and preparation (Capobianco & Rupp, 2014). The present study addresses this gap in the literature regarding elementary level teacher training research as well as student achievement by examining the implementation of PLTW science curriculum in lower elementary levels. Teacher training is also examined as teacher knowledge and ability are one of the top indicators of student success (Mujis & Reynolds, 2015).

Purpose of the Study

The purpose of this case study was to investigate the implementation of PLTW curriculum in first grade classrooms based on teachers' perceptions of the program's effectiveness, teachers' levels of self-efficacy in teaching science, and student achievement at the end of the unit.

Research Questions

The research questions for the study are:

1. What are the teachers' perceptions of PLTW's instructional strategies and effectiveness for science instruction as opposed to instruction using the district curriculum?
2. What are the experiences of the media specialists in working with teachers to implement PLTW? What are the media specialists' perceptions of student engagement and receptiveness to the PLTW program?
3. What are the teachers' perceptions of student achievement following implementation of the PLTW curriculum?

Significance of the Study

STEM subjects can be considered challenging at the elementary level due to factors that range from the subject matter being very abstract to a lack of teacher confidence in the subjects. Young students may not be able to fully grasp abstract concepts, however, they can experiment with these concepts (Hardy, Jonen, & Moller, 2006). For example, preschool students can place different objects in water to see which ones can float. Young students may not be able to explain the scientific theory behind buoyancy and density, but they can notice which items sink or float. Later in their school career, they will use this background knowledge to understand the more complex theories (Ginsburg & Opper, 1969). Teaching elementary school students STEM subjects increases the likelihood that they will remain interested in the subjects and pursue a career in a STEM area (DeJarnette, 2012). Showing teachers who have low self-efficacy in science instruction the positive experiences others have had with an integrated STEM curriculum increases the teachers' willingness to try to teach the STEM curriculum (Bandura, 1977; Holzberger, Philipp, & Mareike, 2013).

Teachers are not typically taught how to teach integrated STEM subjects and many do not have the basic subject knowledge required to teach students these subjects (Gresnigt, Taconis, Keulen, Gravemeijer, & Baartman, 2014; Moore & Smith, 2014). The PLTW curriculum requires teachers to attend extensive professional development, including curriculum training (Nathan, Atwood, Prevost, Phelps, & Tran, 2011). Evaluating the PLTW curriculum could possibly benefit the school and school leaders by providing insight into the teachers' perceptions of the program.

Research Design

This case study was designed to investigate the implementation of the PLTW curriculum in first grade classrooms based on teachers' perceptions of the program's effectiveness, teachers' levels of self-efficacy in teaching science, and student achievement at the end of the unit. An case study design was used in the study with multiple sources of data collected from interviews, a survey, and student achievement scores. All participants were taught the PLTW curriculum. Follow-up interviews with participants focused on their teaching experience with PLTW. Media specialists were also interviewed as they served as co-teachers during the implementation process. Descriptive statistics were applied to examine student achievement scores at the end of the unit.

Case study research is designed to exam a bounded system, such as PLTW, during a detailed and in-depth data collection process (Creswell, 2013). The present case study focused on teachers' experiences with implementing PLTW and its effectiveness. PLTW implementation was chosen because of the importance of STEM education and the availability of the program in the studied district. It was also chosen because even though it is available, it is not utilized by many schools and teachers. The focus of this project is to find out why PLTW is not being utilized more in these settings.

Semi-structured interviews were held with teachers and media specialists who implemented PLTW curriculum and explored teachers' and media specialists' perspectives of integrating PLTW curriculum. Student achievement was measured during the end of unit assessment that was provided as part of the PLTW curriculum. These scores, together with the Teacher Efficacy and Attitudes toward STEM (T-STEM) survey were analyzed using descriptive statistics.

The study used multiple sources of data. The first source was the T-STEM survey developed by the Friday Institute for Educational Innovation (TFI, 2012). The survey measures teacher self-efficacy in science instruction and was sent electronically to all first grade teachers in the district. The survey was conducted to examine the perceptions that teachers have about teaching science. It was expected that teachers with low self-efficacy would be less likely to implement new curriculum than those with high self-efficacy (Bandura, 1982). Studying the self-efficacy of first grade teachers in the district provided data on professional development needs for the district. Teachers are more likely to teach a subject they are knowledgeable about and professional development can be targeted to address the needs identified in the survey. The questions in the survey were asked to identify teachers' beliefs about their level of science content understanding as well as their belief about their ability to teach science.

Assumptions

One assumption of the study was that teachers would answer truthfully during their interviews. Much of the data in this dissertation relies on interview data and validity was established via a member check. It was also assumed that teachers who completed the T-STEM self-efficacy survey would answer their questions honestly to provide accurate data.
I have participated in PLTW-led teacher training, which included an implementation plan. I assumed PLTW was being implemented on a much wider scale than it is due to that aspect of the training. I also expected that PLTW would be popular with those teachers who were teaching it. Another assumption was that the self-efficacy of the teachers implementing the curriculum would be much higher than those that were not.

Limitations

The present study was limited by the lack of a validated and reliable instrument to measure STEM student achievement in early elementary students. Such an assessment could have provided more details on the depth of student learning that occurred during the implementation of the PLTW unit. The study was also limited by studying a single district, although two different schools were included.

Delimitations

I chose the studied district because I am a teacher in the district and therefore had access to other teachers. The PLTW curriculum was chosen because I have had training with the curriculum as a former media specialist and PLTW is an integrated STEM curriculum that was available to teachers. Student achievement was not the focus of the study as I wanted to explore the teachers' reactions to the curriculum. Media specialists were added to the study when it was discovered that there were no teachers willing to implement the curriculum on their own.

Definition of Terms

Integrated STEM Education. The study of science, technology, engineering, and mathematics. These four subjects are combined in a class, unit, or lesson. Students should also implement engineering design to solve a real-world problem (Moore & Smith, 2014).

Constructivist. The application of Piaget's (1969) theory of development that children develop knowledge by actively engaging in their environment and that they construct new knowledge based on their previous knowledge (Siegler & Ellis, 1996).

Project Lead The Way (PLTW). Integrated STEM curriculum that contains teacher training to develop content and curriculum knowledge (Nathan et al., 2011).

Self-efficacy. The belief about oneself (Bandura, 1977). In the present study, it is the belief that one can do something, such as teach integrated STEM education.

Inquiry-based Learning. When students have a question, find a solution, and reflect on their learning as active participants in their learning (Buckner & Kim, 2014).

Differentiated Instruction. Adjusting instruction to meet the needs of all learners (Hilton, 2010). In this study, it is linked to inquiry-based learning.

Summary

The need for integrated STEM education in an elementary school was explored in this chapter. There are very few examples of effective, integrated STEM curriculum for elementary schools and the studied district had already begun to implement the PLTW program. The present study was designed to investigate the implementation of PLTW curriculum in first grade classrooms based on teachers' perceptions of the program's effectiveness, teachers' levels of self-efficacy in teaching science, and student achievement at the end of the unit.

Integrated STEM education is gaining momentum in the education field. The United States federal government supports STEM education with both initiatives and funding (The White House, n.d.). STEM integration efforts are underway, however, there are barriers to overcome. Curriculum is required that provides teacher training, as well as integrates all four subjects of STEM using engineering design to solve a real-life problem. Teachers need to understand the significance of STEM education and see an effective model before they will be willing to try a new approach (Nadelson et al., 2013). In the next chapter, the literature on STEM education will be reviewed including the theories and studies that have been conducted, as well as the areas that are still a concern.

Chapter 2: Literature Review

Proficiency in STEM subjects is important for students as the demand for STEM workers rises sharply in the workplace (Langdon et al., 2011). STEM employment has increased by 24.4% in the last decade compared to 4.0% for non-STEM employment (Noonan, 2017). The projected shortage of STEM workers in 2024 is estimated to be 1,100,000 in the United States (Varas, 2016).

The United States cannot keep up with the demand for STEM workers at the current rate of growth. This is important because it implies a need for change in instruction to increase student interest and to prepare students for STEM courses and careers. Statistics indicate the lack of preparedness in students. The most current international scores from 2015 show 15-year-olds ranked 38 out of 71 countries in math and 24 out of 71 countries in science, and out of the 35 members of the Organization for Economic Cooperation and Development (that sponsors the international testing), the U.S. ranked 30th in math and 19th in science (Desilver, 2017). Therefore, to stay competitive in the global marketplace, the United States needs to make a change to better prepare students for STEM careers (Committee on STEM Education, 2013).

Despite the focus on improving STEM education in the United States, student achievement scores are still low for math and science and students are still not pursuing STEM careers (Epstein & Miller, 2011). It is estimated that interest in STEM science careers drops during high school for males from 13% to 10%, whereas females overall interest in STEM careers drops from almost 16% to almost 13% (Sadler et al., 2012). As students move through their PreK–12 education, their interest in STEM courses and careers drops. Students' self-efficacy in science and math is an indicator of whether they continue to pursue STEM careers or not (Unfried, Faber, Stanhope, & Wiebe, 2015). To develop a high-self-efficacy, science and math instruction needs to begin in early elementary and even early childhood years.

Students are not exposed to STEM subjects in an engaging and meaningful manner during the early elementary grades and therefore their interest in these subjects quickly fades (DeJarnette, 2012; Kermani & Aldemir, 2015; Moore et al., 2014; Sadler et al., 2012; Schmidt & Fulton, 2016). However, early childhood and early elementary years are ideal times to introduce students to STEM subjects as they are naturally curious about the world around them (Aldemir & Kermani, 2016). Allowing students opportunities to experiment and manipulate materials provides a learning environment that leads to deeper understanding of STEM concepts. The foundational knowledge that the students develop at an early age provides base knowledge for subjects that become more abstract and difficult as they continue through school.

Upper elementary and middle school students develop an interest in specific subject areas and consider career paths based upon their previous experiences. Interest in science is often determined before the age of 11 and career aspirations begin as young as 13-years-old (Archer et al., 2010). A study was conducted in an elementary setting with grades two through five and it was found that interest in science was already waning by the fourth and fifth grades (Kurz et al., 2015). It is vital to develop an interest in STEM subjects and career paths for students before their interests diminish and to entice more students to continue to pursue STEM careers (Kermani & Aldemir, 2015).

The focus of this literature review is on the research concerning STEM education. Research issued by the federal government was explored to determine the current state of STEM education in the United States as many initiatives have been released in the last decade that promote STEM education. Research was also conducted on PLTW, which is the integrated curriculum model chosen for this research study (PLTW, 2014). The theoretical framework was established using Piaget's (1969) theory of cognitive development, Dewey's (1916) theory of learning by doing, and constructivism (Siegler & Ellis, 1996). Research on 21st century skills were explored such as complex communication, social skills, and systems thinking because they have become an integral part of STEM education (Bybee, 2010). Employers identify 21st century skills as being vital in the workplace (Pellegrino & Hilton, 2012). Employees must be able to think and adapt to different situations as well as work with others and communicate efficiently and effectively (Hilton, 2010). PLTW provides an opportunity for students to practice these skills by using a problem-based approach.

Several searches were conducted on the internet to locate the most current policies from the United States Department of Education, as well as congressional committee reports on STEM, STEM education, and STEM as related to the global job market. The primary database that was used to search for articles for this literature review was the Education Resources Information Center database, with ProQuest being the secondary database. Search terms used were STEM education, integrating STEM, Project Lead The Way, STEM and early elementary, Dewey, Piaget, constructivism, 21st century learning skills, self-efficacy, inquiry-based learning, project-based learning, Next Generation Science Standards, STEM integration teacher training, and STEM integration preservice teacher training.

Conceptual Framework

The conceptual framework for the present study was based in part on the work of Piaget & Inhelder (1969) and Dewey (1916). Piaget & Inhelder (1969) developed a continuum of learning that begins at birth and continues through the teenage years. Their work provides teachers with guidance of where students are in their learning and how to structure activities to maximize learning. For young children, who are still concrete learners, this does not mean that abstract concepts cannot be explored (Smith, 1981). It simply means they must be explored in a hands-on way that allows the children to construct their own knowledge about the concept. Dewey (1916) further elaborated on the active engagement of learners with his belief being that students need to see the connection between what they are learning and the real-world application.

Piaget and Inhelder's (1969) theory describes the cognitive functions of children in their early learning years and beyond. Four stages of development were identified in this study: sensorimotor, preoperational, concrete-operational, and formal operational (Piaget & Inhelder, 1969). These stages build upon one another and children move through them at their own pace. The preschool, kindergarten, and part of first grade years occur during the preoperational stage, which occurs from approximately two to seven years of age (Piaget & Inhelder, 1969). This is the stage when language is learned and when children are learning to think logically through exploration of their world (Smith, 1981). At this stage, children can only hold one attribute of an object in their mind at one time and are unable to recognize a transformation in an object (Piaget & Inhelder, 1969). The authors conducted an experiment involving water with children in the preoperational stage. Water was poured from two different sized containers. Preoperational children were not able to recognize that there was the same amount of water in both containers, as the taller and thinner container appeared to contain more than the shorter and wider container (Piaget & Inhelder, 1969).

Toward the end of the first grade, students should be moving into Piaget and Inhelder's (1969) next stage, the concrete-operational stage. This stage generally occurs between seven and twelve years of age. Students in this stage of development would see that the containers of water (from the above experiment) are shaped differently or would recognize that when poured back and forth, the amount of water remains the same. Concrete-operational children can understand that an object can have more than one attribute and can classify the objects by attribute (Piaget & Inhelder, 1969). Children learn at different paces, therefore it is possible some will reach this stage and some will not. First grade teachers need to be aware of the shift that is occurring so they can support and enrich those students who have reached this stage while still providing activities that are age appropriate for those students that are not quite there yet.

Children learn by doing. For children to understand the world around them, they must experience it (Glassman & Whaley, 2000). Dewey (1916) believed students should not simply sit and listen to a teacher speak but should be given opportunities to actively apply what they are learning. The role of the teacher is to provide guidance for learning and to ensure that students are on task to complete their goals without impeding on their learning (Glassman & Whaley, 2000). It is important for a teacher to guide and oversee the exploration to ensure that the student is interpreting the results correctly. Educating a child is a social encounter and we learn by our experiences. Just having experiences, however, does not mean learning is occurring. The learning occurs when those experiences are reflected upon (Dewey, 1916).

Constructivism has many different types, such as individual, social, cognitive, and radical (Gordon, 2009). Even though there are many interpretations of what constructivism means, the belief is that active learning is a key component (Crowther, 1999). Learners need to know why they are learning and they need to have ownership of the process (Savery & Duffy, 1995). When learners are partners in their learning it also activates cognitive engagement, which makes learners more susceptible to learning than if they were simply receiving the information (Hardy et al., 2006).

Integrated STEM education follows the constructivist view by taking an abstract concept and allowing children to create their own knowledge via hands-on learning (Sanders, 2009). An example from math in the younger years would be using manipulatives in math lessons. First, students need to practice counting objects to understand that each number represents a group of objects. When the lessons move into addition and subtraction, students use manipulatives to demonstrate their understanding of more or less with the objects.

Dewey (1916) also proposed that education should promote citizenship. Responsible citizens are ones who investigate the issues, not ones who simply believe what others are saying. Children need to learn how to examine a concept and work to develop an understanding. Developing the skills needed to think through a concept allows students to make informed decisions and adapt to the world around them when they become adults.

STEM educators work to create experiences that allow students to explore and manipulate materials to determine meaning. Both project-based learning and cooperative learning are rooted in constructivist theory (Verma, Dickerson, & McKinney, 2011). Integrated STEM education requires students to take the knowledge they have and apply it to other disciplines while solving real-world problems; thus, students are constructing new knowledge by trying out ideas based on their prior knowledge and making adjustments as they go through the process (Sanders, 2009). Students need to fail so they learn how to examine their results and then try again (Moore & Smith, 2014).

Bandura (1977) developed the theory of self-efficacy to describe a person’s beliefs about their abilities. How people perceive themselves and their abilities affects their decisions and actions. For teachers, this can mean that if they perceive themselves as not being knowledgeable about a subject, such as science, they will be more hesitant to teach that subject (or will simply avoid teaching that subject) (Yoon et al., 2014). STEM subjects tend to be areas that teachers have low self-efficacy in and therefore are hesitant to teach (Rich, Jones, Belikov, Yoshikawa, & Perkins, 2017).

Background of STEM

The term STEM was coined by Judith A. Ramaley, a former director of the National Science Foundation's Human Resources Division during the 1990s simply as a shortened acronym for the four subjects of science, technology, engineering, and mathematics (Koonce, Zhou, Anderson, Hening, & Martin Conley, 2011). STEM began as a political campaign to develop a more competent workforce (Blackley & Howell, 2015; Sadler et al., 2012). STEM education grew out of the need for better educated workers to fill the growing number of STEM careers (Blackley & Howell, 2015). The United States is producing fewer STEM employees and professionals and there are not enough students interested in STEM careers to fill the job openings (Schmidt & Fulton, 2016). In addition, more jobs are requiring STEM skills, making the need for higher STEM education even greater (Noonan, 2017).

Only a small percentage of students pursue STEM careers (The Alliance for Science & Technology Research in America, 2016) and the number of students entering STEM fields once they have finished their studies is decreasing (Cannady, Greenwald, & Harris, 2014). The goal of integrated STEM education is to increase the number of students who select STEM fields (Moore et al., 2014)

Integrated STEM education approaches increase students' interest in STEM subjects and career fields (Sanders, 2019). Early STEM career interest has a large effect on late STEM career interest and experiences prior to high school are key (Sadler et al., 2012). Integrated STEM instruction in the elementary years increases interest in STEM overall (Yang et al., 2015).

Researchers are discovering that elementary school is the ideal time to develop student interest in STEM fields (DeJarnette, 2012; Moore et al., 2014; Sadler et al., 2012; Schmidt & Fulton, 2016). During early elementary years, students are naturally curious and like to explore topics. This natural curiosity can be nurtured and developed to create students that are inquisitive and not afraid to experiment until they find the right answer. Developing a foundation for STEM subjects can lead to increased interest in STEM during high school and beyond (DeJarnette, 2012).

More research is being conducted that shows that the earlier STEM is introduced, the more likely a student is to continue to pursue a STEM career (Kurz et al., 2015; Sadler et al., 2012; Sanders, 2009; Tai, 2012). A strong foundation needs to be established during early childhood and early elementary years that will develop students' interest and abilities in STEM fields (Sadler et al., 2012). To assist states in developing integrated STEM education, the National Research Council (2013) released a framework that was used to then develop new science standards for K–12 science education.

A report from The Carnegie Corporation of New York (2007) examined the United States' education system in regards to math and science education. The report found that not only is a change required in math and science curriculum, but changes need to occur for the entire United States' educational system (The Carnegie Corporation of New York, 2007). The Carnegie Corporation of New York (2007) suggested fewer standards at each level that developed deeper knowledge and these standards be accompanied by assessments aligned to the new levels. All students should be provided with science instruction, not just those who can afford to attend schools that provide instruction. The report also declared the need for teachers that are better prepared to teach science and math classes (The Carnegie Corporation of New York, 2007).

In response to The Carnegie Corporation of New York (2007), new science standards (NGSS) were developed. The first step in the development of the standards was a document called *A Framework for K-12 Science Education* (Quinn et al., 2012). The *Framework* includes a vision for science education, the content to teach, and how to realize the vision (Bybee, 2014). The *Framework* was developed using the most current research on science and learning and involved experts including science education researchers and practicing scientists (Bybee, 2014). Three dimensions were identified to build standards as follows: scientific and engineering practices, crosscutting concepts, and core ideas in four disciplines (Quinn et al., 2012). The *Framework* also recommended depth instead of breadth, meaning science concepts should be studied at a deeper level, with fewer standards at each grade level.

The next step involved business partners, educators, and teams from 26 US states. These groups examined the standards and provided feedback on their development. The final draft was developed after multiple reviews, including two public drafts. The NGSS were also reviewed by the National Research Council and were found to follow the recommendations from the *Framework* (Bybee, 2014).

Next Generation Science Standards (NGSS)

NGSS provide performance expectations for which all students are held accountable (NGSS, 2016). The standards were designed to focus on fewer science concepts at a deeper level (Pruitt, 2014). NGSS combine science and engineering concepts into standards that clearly show educators what comprehensive science knowledge should look like using engineering design as a method for teaching science content (Lee, Miller, & Januszyk, 2014; Moore & Smith, 2014).

Integrating engineering design is an effective method for delivering science content to students (Roehrig, Moore, Want, & Park, 2012). The standards were developed for many of the same reasons as STEM was, i.e., to help students become college and career ready for jobs in the fields of science, technology, engineering, and math (NGSS, 2016).

These standards also represent a new way of teaching, although they are not curriculum (NGSS, 2013). Teachers are encouraged to teach science as an inquiry process, giving students a hands-on activity and having them conduct experiments with specific outcomes in mind. Students need to be allowed to develop the experiment that will answer the question they have posed, then conduct the experiment and make adjustments based on the outcomes of the experiment (Osborne, 2014).

NGSS provide standards to improve the quality of science education in the United States (National Research Council, 2013). The efforts so far to make a change in the teaching of science is not making many gains (Epstein & Miller, 2011). The first step in that change is a new and improved set of standards that promote the use of science and engineering together to help students move past a rote memorization of facts into a deeper learning of science standards (Lee et al., 2014). For many states, this is the first time that engineering has been placed in science standards (Pruitt, 2014). Integrated STEM education is the vehicle that states need to implement the new standards.

This shift moves the focus from simply understanding content to applying ideas and allows students to engage in science and engineering practices in the same way as their real-world counterparts (Huff, 2016). States are using these standards to guide implementation of STEM integration (Roehrig et al., 2012). No longer are concepts being taught in isolation (biology, chemistry, and so on), rather now they are being integrated for students to see how they connect and the importance each discipline has to other disciplines.

Federally Sponsored Reports on STEM

In the budget for the 2017 fiscal year, the United States federal government allotted millions of dollars to STEM education (White House Office of Science and Technology Policy, 2016). This funding supports active learning in the STEM fields and funds are also being allocated to teacher training (White House Office of Science and Technology Policy, 2016). Teacher training is required in science pedagogy for both preservice teachers and veteran teachers (Avery & Reeve, 2013; Epstein & Miller, 2011; Murphy & Mancini-Samuelson, 2012).

There have been several reports released at the federal level in the last decade addressing the lagging scores and the need for change in STEM education. The *Prepare and Inspire* report (President's Council of Advisors on Science and Technology, 2010) discusses STEM careers and education and what needs to be done to not only increase the achievement of students in STEM subjects in school, but also increase students' interest in pursuing STEM careers. According to the report, even high-achieving students in STEM subjects are not pursuing STEM careers. The Council highlighted the need for student proficiency in STEM subjects, to inspire students to pursue STEM subjects and careers, and to create a cohesive approach to improving STEM in the United States (President's Council of Advisors on Science and Technology, 2010).

The next major STEM report was the *Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education Investments: Progress Report* (CoSTEM) report in 2012. It was created in response to the reauthorization of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act of 2007, or America COMPETES Act of 2007 (National Science and Technology Council, 2012). The first American COMPETES Act of 2007, which provided funding for basic research programs, improved instruction in math, and advanced placement/international baccalaureate classes (Office of the Press Secretary, 2007). The Act was reauthorized in 2010, raising the funding amount for the Department of Energy's Office of Science, the National Institute of Standards and Technology, and the National Science Foundation (Holdren, 2011).

The *Progress Report* developed a plan to coordinate investments in STEM education. It established a common vision, common goals, and common objectives for federal STEM education initiatives (Committee on STEM Education, 2013). The plan established four objectives to achieve coordination, with the first objective using evidence-based approaches to align with current evidence-based practices in education. This objective requires documents to be continually updated on an annual basis. The second objective was to identify and share these evidence-based approaches. This objective established an evaluation process for STEM education and a plan for disseminating new information. An increase in efficiency and coherence would be established using inter-agency coordination and collaboration and was the third objective of the strategic plan. Finally, the plan called for investments to focus on priority areas, such as effective K-12 STEM teacher education, engagement in STEM, undergraduate STEM education, and serving groups traditionally underrepresented. Investments would be focused on these four areas, although other areas would also be considered for funds.

The strategic plan was outlined in the CoSTEM Progress Report and called for a focus on five areas. These areas are to improve STEM instruction, increase and sustain youth and public engagement in STEM, enhance STEM experiences of undergraduate students, better serve groups historically underrepresented in STEM fields, and design graduate education for tomorrow's STEM workforce. The plan was established to see enhanced and sustained improvement in these five areas.

To improve STEM instruction, CoSTEM agencies aim to help 100,000 new teachers obtain an excellent STEM education, as well as support existing teachers in STEM education. Short-term goals include retaining effective STEM teachers as well as providing incentives for training excellent K–12 STEM teachers. Mid-range goals involve using the evidence base to develop federal programs to recruit and retain excellent K–12 teachers. The long-term goals are to federally fund recruitment and retention and evidence-based practices, as well as collect data on the impact of these initiatives.

The second area, increase and sustain youth and public engagement in STEM, already has many CoSTEM agencies involved. This goal was established to increase society's awareness of STEM learning opportunities for both youth and adults. To progress as a nation, the entire public must understand the importance of STEM in our society and engage with STEM in informal settings. This type of engagement can allow learners to develop interest in STEM fields by providing positive experiences. One example is the United States Department of Agriculture's (USDA) involvement with youth 4-H groups. To increase engagement in school readiness and afterschool programs, the short-term goal is to identify and collaborate with existing programs, such as 4-H and Head Start. The mid-term goal is to establish a partnership with these agencies to meet the long-term goal of establishing longitudinal studies on outcomes of STEM engagement and experiences.

To enhance STEM experiences of undergraduate students, data must be collected on current instructional practices. Once that short-term goal has been reached, partnerships will need to be developed between stakeholders and faculty to implement evidence-based practices.

Stakeholders will validate the relationship of practices to student outcomes to reach the long-term goal.

The fourth priority is to better serve groups that have been historically underrepresented in STEM fields. This priority will be accomplished by first identifying issues and concerns and encouraging new ideas on how to better represent all groups in STEM education. A short-term goal is to increase internships at the federal level for underrepresented groups. To extend this goal, partnerships will then be developed to design or redesign courses that are relevant to underrepresented groups. In the long-term, databases will monitor the progress of the groups' representation in STEM. The final priority identified is to design graduate education for tomorrow's STEM workforce. A coordinated approach will be established that will provide a comprehensive area for candidates to approach fellowships in STEM fields.

To track the recommended changes, a progress report has been released each year. The report outlines where spending has occurred and where it still needs to occur to enact the changes suggested by the previous reports. In the 2016 report, there were three major funding areas identified: expanding access to rigorous STEM courses, improving the teaching of STEM, and expanding opportunities for all students in STEM (Office of Science and Technology Policy, 2016). Expanding access includes funding for high schools to offer more advanced STEM courses, such as calculus and physics. A recent survey reported that half of American high schools do not offer calculus and 27% do not offer physics (Office of Science and Technology Policy, 2016). Expanding computer science courses is included in this funding category as it is estimated only one quarter of schools offer computer science courses (Office of Science and Technology Policy, 2016). The second area of improving STEM teaching and supporting active learning provides funds to develop content knowledge in current and preservice teachers (Office of Science and Technology Policy, 2016). The third category of expanding opportunities for all students in STEM focuses on bringing STEM opportunities to traditionally underrepresented groups.

The federal reports have guided reform for STEM education during the Obama administration. Grants were funded in 2017 that promote high-quality STEM and computer science education (Office of Science and Technology Policy, 2017). These policies and funding initiatives provide schools with the means to implement and integrate high-quality STEM education.

Implementing and Integrating STEM

Each discipline in STEM education has its own knowledge base regarding practices and skills that are most appropriate and effective for teaching that discipline (Honey, Pearson, & Schweingruber, 2014). Traditionally, the United States has used a "silo" approach when it comes to curriculum, where the disciplines are presented in separate classes or at separate times of the day (Bybee, 2010). At the elementary level, the same teacher delivers instruction in all subjects, but does so at scheduled times for separate subjects. The time spent on each subject varies and, traditionally, the focus has been on reading and math (Lewis, 2008). Recent trends for time spent on subjects have been driven by mandated testing. With the *No Child Left Behind Act* came mandated testing, and the main subjects being tested were reading and math (testing began in these subjects in 2003). Science testing does take place, however, such testing was not implemented until 2007, and it is not used to measure adequate yearly progress (Blank, 2012). The focus on testing and making progress has resulted in less time for other subjects (Lewis, 2008).

Educators have more experience and comfort levels in integrating science and math as they are more common in state standards and curriculum (Guzey et al., 2016). These two subjects have standards, curricula, and teacher education programs dedicated to teaching science and math to students (National Academy of Engineering and National Research Council, 2009). Science and math also have similar process standards, which means students learn them in similar ways (Bosse, Lee, Swinson, & Faulconer, 2010).

For many states, the NGSS represent the first time that engineering has been included in elementary curriculum (Pruitt, 2014), with engineering being utilized even less than technology in elementary curriculum (National Academy of Engineering and National Research Council, 2009). Historically, engineering is not a subject that was prevalent in elementary education, although its presence is now growing (National Academy of Engineering and National Research Council, 2009). Young elementary students often have confusing ideas on what an engineer does, many times confusing them with a train engineer (Pantoya, Aguirre-Munoz, & Hunt, 2015). There is a place for engineering at all levels of education when implemented correctly.

The NGSS require that states use engineering as one method for teaching science concepts (Moore & Smith, 2014). STEM education is important to the future of our nation. The United States is projected to have more growth in STEM career fields than that in STEM workers over the next 15 years (Varas, 2016). Therefore, STEM education in elementary schools needs to be improved to develop students that are interested and motivated to pursue careers in STEM fields (President's Council of Advisors on Science and Technology, 2010). One way to accomplish this goal is by integrating STEM subjects with engineering as the delivery method for real-world learning (Moore & Smith, 2014).

There are two types of integration, context integration and content integration. Context integration is when engineering is used to motivate students, however, the learning goals are generally focused on the other subjects (Moore & Smith, 2014). Content integration is when engineering concepts are included in the learning goals, along with math, science, and technology (Moore & Smith, 2014). Context integration is used most often. In context integration, the learning focus is on the math or science content, with technology and engineering design being utilized to solve the problem that is presented.

NGSS involve including engineering in the learning process. Teachers will generally begin with context integration, using the engineering design process as a motivational tool. As teachers become more comfortable with their teaching, they can move into more of a content integration approach, teaching about engineering standards as well as science standards (Moore & Smith, 2014).

There are several elements that should be present for a lesson, class, or unit to be considered high-quality STEM integration. The context should be motivating and interesting with a real-world connection to engage students. There should be an engineering design challenge included. Students should be encouraged to develop theories and test them because students learn as much from failing as they do from succeeding. The activities should be student-centered, meaning the students are leading the learning and are actively engaged in the activity. Students should work in teams to develop social and communication skills (Guzey et al., 2016; Moore et al., 2014)

Not only should the subjects be taught together in an integrated STEM unit, but they should also culminate in a challenge that is based on a real-life issue (Guzey et al., 2016). The real-life problem shows students that what they are learning is applicable and meaningful, which will engage them in the learning. Engineering design is used to provide real-world connections with science, math, and technology and show how these subjects work together (Yoon et al., 2014). This integration is not easily accomplished and takes considerable planning (Williams, 2011). At the elementary level, this integration can be done with lessons taught through themes that incorporate multiple aspects such as math, technology, and science. At the secondary level, teachers can collaborate to integrate the sciences with other subject areas.

Constructivists focus on helping students make meaningful connections with their learning materials as well as between ideas (Bosse et al., 2010). Expertise is developed when students make connections in their learning and discover how those ideas are connected (Honey et al., 2014). To maximize learning, students must be engaged, given time to explore, develop explanations of their findings, elaborate and extend their findings, and evaluate the outcomes. This process helps students activate their prior knowledge, then sets them up to explore the topic and create meaning from the new material (Bosse et al., 2010). Integrated STEM education follows a similar process of engaging students. An engaging lesson would include exploration time, developing and elaborating on students' ideas, and extending and evaluating students' outcomes.

Traditional education presents subjects as being separate and they are taught as such, with very little connections made between the subjects (Bybee, 2010). At times, it is appropriate to isolate a subject for instruction. Separate and explicit instruction of a topic still has a place in education as each discipline has its own methods of instruction and its own continuum of development (Honey et al., 2014). The strength of integrated STEM education lies in its ability to mirror jobs in the real world. It often takes an understanding of how different subjects and components interact to solve a problem (Roehrig et al., 2012). It also requires critical thinking, problem solving, creativity, and innovation. These components are part of the 21^{st} century learning skills (Pellegrino & Hilton, 2012).

Even though evidence shows that students with integrated curriculum perform better than those students with standard curriculum (Sanders, 2009), it is hard to enact educational reform. Full integration requires undertaking a new approach to teaching that is not familiar to some teachers (Williams, 2011). STEM integration does not have to occur in a full program overhaul. Instead, it can begin with just one unit. Bybee (2010) suggests taking one unit and moving it into a STEM integration unit, which can be accommodated more easily than a full program change. Integrating one unit at a time gives teachers the opportunity to see the benefits of true STEM integration without overwhelming them with an entirely new curriculum and method of teaching. Teachers have developed their own knowledge base of how to teach and what works best based on their years of experience. Teachers are often resistant to an entirely new method because it goes against what they have experience in (Guzey et al., 2016). Providing one unit at a time can help ease them into this new method of STEM integration.

Technology and STEM

As technology has become more prevalent in society, so too has its place in the education system (National Academy of Engineering and National Research Council, 2009). However, teachers are not keeping up with technology trends in the classroom (Pittman & Gaines, 2015). Technology is often used as a learning tool to deliver the more standard content of language arts, reading, math, science, or social studies, which is not true integration (Williams, 2011). Technology cannot just be given to teachers; there must be training, support, and follow-up for it to be effectively integrated into the curriculum.

Integrating technology can allow children to discover new content for themselves and learn to construct meaning. It also allows students to be actively engaged in their learning (Buckner & Kim, 2014). When implemented correctly, technology can be a powerful tool in inquiry-based learning. Technology can represent real-world problems more richly, allowing students to become even more engrossed in their learning (Wang, Kinzie, McGuire, & Pan, 2009).

Young children have the capacity to learn technology skills in early elementary grades. Piaget & Inhelder's (1969) stages suggest young children around the ages of 6–10 years are capable of learning how technology works, yet technology education is not formally taught until secondary school (Katsioloudis, 2015). While young students are utilizing technology, it is often more as a tool for practicing another content, not for the technology itself (Williams, 2001). For example, they may be using a flashcard app on an iPad to practice their sight words. This approach should not be discounted as children that are still in preschool (ages 3–5 years) can begin to use iPads to practice skills and become comfortable with technology (Aldemir & Kermani, 2016). However, true technology education goes beyond just practicing skills.

Technology education is viewed as the tools that are used by students (and practitioners) in science, mathematics, and engineering (Honey et al., 2014). Technology tools provide students with the understanding of how technology works, and how it can be utilized to study other fields. Technology is taught in upper grades as a stand-alone subject, yet it is more powerful when integrated into other areas such as in STEM education.

In *A Framework for K-12 Science Education*, the guiding report used to create the NGSS (National Research Council, 2013), technology is defined as a "modification of the natural world made to fulfill human needs or desires" (Quinn et al., 2012, p. 202). Scientists use the tools of technology when conducting experiments, and often again when interpreting the results, making technology a method used to explore the natural world (Honey et al., 2014). Integrating technology with science, mathematics, and engineering makes sense as technology is often used when working in all three disciplines. As with STEM subjects in general, the key to technology integration is teacher training. Teacher need to be trained in the tools they currently have access to at the time of the training. Training is more effective when they see the technology being modeled in the classroom and have time to practice with support (Pittman & Gaines, 2015).

Teacher Training

Teacher training is two-fold: preservice teacher training and current teacher training. Both preservice teachers and current teachers need more training in STEM content knowledge and STEM integration practices.

Professional Development for Current Teachers

Training and professional development are needed for STEM integration to occur effectively and efficiently in classrooms. Many studies discuss the lack of professional development in science for teachers and the need for more training in implementing integrated STEM education and in developing the content knowledge in STEM subjects for K–12 teachers (Blackley & Howell, 2015; Capobianco & Rupp, 2014; Roehrig et al., 2012; Williams, 2011). Teachers who do not possess the appropriate content knowledge that is required to teach a unit will often simply not teach it out of concern that she or he will not know the answers to student questions (Yoon et al., 2014). There is a link between a teacher’s content knowledge and their effectiveness in teaching a subject (Nadelson et al., 2012). Therefore, teachers need an increased level of content knowledge.

To assist teachers with implementing integrated STEM education, professional development is required to provide teachers with a deep and thorough understanding of the topics and how to integrate them (Avery & Reeve, 2013). This can be accomplished by providing a strong rationale (Avery & Reeve, 2013) and vertical alignment in the STEM subjects, as well as having school districts partner with local universities and colleges, and even by implementing a mentor program to assist novice teachers (Yang et al., 2015). Professional development must provide teachers with a supportive learning environment for them to become comfortable enough with the subject matter to teach it (Avery & Reeve, 2013). Teacher efficacy is directly related to comfort with the subject being taught. Teacher training to develop knowledge and comfort in the subjects of STEM, as well as integrating them into existing curriculum and programming, is necessary to implement the policies being created (Nadelson et al., 2012).

Preservice Teacher Training

Teachers are more likely to make a change in their teaching when they see it modeled effectively (Nadelson et al., 2013). Integrating STEM education at the collegiate level results in preservice teachers not only experiencing integrated STEM as a model, but also results in increased content knowledge and competence (Murphy & Mancini-Samuelson, 2012). A university in Australia has developed a science and math school at a university campus as a method of working toward increasing STEM interest (Bissaker, 2014).

The benefit of locating the school on the campus was that the teachers had access to the academic experts at the college (Bissaker, 2014). At the same time, the college was able to see the challenges and barriers that exist in the public school system for teachers and students. The adults at the public school and at the college were participating in an adult version of integrated

STEM education. They had to learn new content through a hands-on learning approach and they had to accomplish their goals as a team.

Preservice teachers also require STEM integration training as many programs are lacking in their basic requirements of math and science classes (Schmidt & Fulton, 2016). Preservice teachers, while required to take science and math courses, do not often have a strong knowledge base of either one (Schmidt & Fulton, 2016). Epstein & Miller (2011) suggest a complete overhaul of teacher education programs, starting with the acceptance criteria and ending with a certification test. More math and science classes are being suggested in teacher education programs, but so far not much has changed (Epstein & Miller, 2011). While changes need to be made, having more stringent acceptance criteria may not be the place to start as there is much more to teaching than scoring well on a test.

Inquiry-Based and Project-Based Learning

Students develop ideas and theories about a topic based on questioning, data collection, reasoning, and reviewing the data when engaged in inquiry learning (Ramnarain, 2014). Pedaste et al. (2015) conducted a review of the literature on inquiry-based learning to develop a synthesized inquiry cycle. The resulting inquiry cycle consisted of five phases and seven sub-phases. The phases included orientation, conceptualization, investigation, conclusion, and discussion, and questioning and hypothesis generation in the sub-phases. Exploration, experimentation, and data interpretation are all sub-phases of the investigation phase. The discussion phase is broken down into the sub-phases of communication and reflection (Pedaste et al., 2015). The cycle is not limited to one step after another, but rather flows as the inquiry occurs, often repeating and combining steps. Inquiry-based learning follows the scientific steps of inquiry, much as scientists do in their daily work.

Project-based learning is when students are given a problem to solve and they must work toward the solution on their own (Nadelson et al., 2013). Project-based learning is designed to connect learning to real-world problems (Kaldi, Filippatou, & Govaris, 2011). Student background knowledge is activated and past experiences are applied to the new learning, making project-based learning more inclusive to all learners (Kaldi et al., 2011).

STEM lessons utilize inquiry-based learning, as this is a primary example of how real scientists go about solving problems and making discoveries (Abdi, 2014). Inquiry-based learning also helps students understand how things work in the real-world and that they must be able to think and solve problems (Wang et al., 2009). Although problem solving is not explicitly written into STEM education, it is a common element in STEM education curriculum (Honey et al., 2014).

A primary goal of inquiry-based learning is to engage students and give them a sense of control over their learning (Litmanen, Lonka, Inkinen, Lipponen, & Hakkarainen, 2012). The inquiry-based learning process helps guide students to become independent learners (Litmanen et al., 2012). Although inquiry-based learning is generally a strategy used in science and math classes, the inquiry-based process also promotes language and literacy (Wang et al., 2009). Inquiry-based learning also has a positive side effect, i.e., fewer students act out and misbehave when they are involved in an inquiry-based lesson (Sever & Guven, 2014). Litmanen et al. (2012) report that a task must be just slightly challenging to fully engage students, and inquiry-based learning provides an opportunity to tailor projects to the education level of the students.

Project Lead The Way (PLTW)

PLTW was developed in 1986 by a teacher in Upstate New York. The teacher recognized the lack of engineering opportunities for students, and thus developed new courses to compensate for this lack (PLTW, 2014). In 1997, after ten years of successful course development, a local foundation sponsored the lesson project and developed PLTW into what is now known as the Engineering Program (PLTW, 2014). A dozen schools began using the PLTW curriculum that year and by 2008 the organization-spread to all 50 states and Washington, D.C. (PLTW, 2014). There are now five separate programs that offer classes in K–12 for computer science, engineering, and biomedical science (PLTW, 2014). In 2004, PLTW was recommended as an exemplary program by the U.S. Department of Education and in 2016 the White House acknowledged PLTW's leadership in K–12 computer science education (PLTW, 2014).

PLTW curriculum begins in elementary school with the Launch program. Elementary teachers are provided curriculum in computer science, engineering, and biomedical science that is aligned to both Common Core standards in English and math and the NGSS. The Launch curriculum begins with a story about Mylo, Suzi, and Angelina. The story establishes the problem that the students will be solving during the unit, and the three characters grow up with the students as they move through elementary school. In the elementary school light and sound unit, the characters are lost and need to communicate using only light and sound.

When students attend middle school, they move into the PLTW Gateway curriculum. There are ten Gateway courses: Design and Modeling, Automation and Robotics, Introduction to Computer Science I and II, Energy and the Environment, Flight and Space, Science of Technology, Magic of Electrons, Green Architecture, and Medical Detectives. The Gateway curriculum continues to provide students with hands-on learning about real-world problems, similar to the Launch curriculum.

PLTW for high school is divided into the three topics that were taught in the Launch curriculum and the Gateway curriculum: computer science, engineering, and biomedical science. These topics are all taught together throughout the Launch and Gateway curriculum, but at the high school level they are divided into paths. PLTW lessons are developed using the guidelines of collaboration, research/evidence- based, and problem-based (PLTW, 2014). The developers of the program collaborated by seeking feedback from students, teachers, administrators, and leaders in each subject field. The courses are also aligned with state standards and Common Core (PLTW, 2014).

There are few studies that have looked at the impact PLTW has had on student achievement and performance on a large scale (Van Overschelde, 2013). Van Overschelde (2013) corrected this oversight by conducting a study that tracked students for six years, who took two or more PLTW courses. Van Overschelde (2013) included a large sample size and examined those who did and did not go to college. The PLTW students consistently scored higher in math and had a higher tendency to go to college than the non-PLTW students. The PLTW students that did not attend a higher education institution had higher median wages than the wages of the students that did not enroll in PLTW (Van Overschelde, 2013).

Another study was conducted to determine whether PLTW students could transfer their learning outside of their coursework (Dixon & Brown, 2012). When students transfer their learning, it means they understand the material at a deep enough level to apply it to other situations. For example, after completing a STEM unit on animal habitats, kindergarten students were on a field trip and were using the term “habitat” correctly with the tour guide (Tank, Pettis, Moore, & Fehr, 2013). The results showed that PLTW students scored higher on the design process than students not taking PLTW courses, although only a small percentage connected the math and science learned (Dixon & Brown, 2012). Transfer of learning is the ultimate goal of education and one that is difficult to achieve. Engaging students in lessons that require reflection can aid them in learning to make these connections (Dixon & Brown, 2012). Students also require the support of their teachers to assist them in learning to see how these subjects are connected.

21st Century Learning Skills

Students begin kindergarten at five years old and end their elementary career around the age of ten. Just providing students with content knowledge is simply not enough. Teachers need to teach students how to solve a problem and how to work through failure. Students need to know how to work on a team and how to persevere even when tasks are hard. Integrated STEM education provides an excellent opportunity to incorporate these "soft skills" (Jacobson-Lundeberg, 2016).

Soft skills can also be referred to as 21st century learning skills that have been defined as adaptability, complex communication/social skills, non-routine problem-solving skills, self-management/self-development, and systems thinking (Hilton, 2010). These skills have also been divided into three domains: cognitive, intrapersonal, and interpersonal (Hilton, 2010), and align with some of the goals of inquiry-based learning, especially communication (Pedaste et al., 2015). Students must communicate with each other and the teacher when involved in inquiry-based learning. Thus, their interpersonal skills should be able to develop alongside their science and math skills.

The National Research Council included skills such as adaptability, complex communication skills, and solving non-routine problems as required workplace skills (Hilton, 2010). These skills are valuable work-related skills (Hilton, 2010). Developing student workplace skills enable students to become knowledgeable workers who also have a solid work ethic (Blackley & Howell, 2015).

The United States is not the only country that is paying attention to STEM education and 21st century learning skills. South Africa is still struggling with post-apartheid segregation problems and, as such, many of their Black citizens are not receiving the same quality of education owing to unequitable resources (Ramnarain, 2014). In the study conducted, Ramnarain (2014) discovered similar issues with integrating an inquiry-based curriculum as the United States is observing. In addition to the unequitable facilities, teacher training and access to resources was a hindrance to implementing inquiry-based learning (Ramnarain, 2014).

The education system in Kenya has been developed with the teacher as the one in control, who is the one that holds the knowledge and passes it along (Kafwa, Gaudience, & Kisaka, 2015). The physical, emotional, social, intellectual, and spiritual well-being are the aspects of a holistic learner, and teachers control the content and pace of learning with little input from the learner (Kafwa et al., 2015). With the advances of technology and the changes in the global society, Kenya is now seeking what changes need to be made in their education system. One change being examined is the switch to a learner-centered approach that incorporate 21st century skills such as technology skills that are acquired through authentic learning environments (Kafwa et al., 2015).

Other African governments are working on establishing new goals for their secondary education students in the form of life skills (Akyeampong, 2014). In Ghana, only 35% of students move on to upper secondary education and the poverty levels often do not allow them any vocational training. The view is that the technology and job markets are so difficult to predict that students need life skills to be successful instead of specific content knowledge (Akyeampong, 2014).

Students of all backgrounds and socioeconomic levels need to develop 21st century skills. Countries in Africa that do not have as much access to technology as the United States are still seeing the importance of these skills. These countries are also looking to educate workers who will be competitive in the global job market (Akyeampong, 2014; Kafwa et al., 2015). Developing 21st century skills in today's students is vital for keeping up with the changes and advances our society makes, not only in the United States but worldwide.

Teacher Self-Efficacy

A teacher's self-efficacy is the belief that teacher holds that she or he can achieve a task. For teachers, that generally translates to their belief in their ability to help students meet the goals and objectives of the lesson (Holzberger et al., 2013). A relationship exists between teacher self-efficacy and student achievement. The more effective a teacher is, the better the students achieve (Mujis & Reynolds, 2015). Students achieve at higher levels when in a class with a teacher who has higher self-efficacy (Mojavezi & Tamiz, 2012). Students who perceive their teachers have high expectations and goals for students will also perform better than students who do not have this perception (Jiang, Song, Lee, & Bong, 2014). Teachers with high self-efficacy have been found to also believe that lower achieving students can achieve more, making them more persistent when working with these students (Mojavezi & Tamiz, 2012).

Training teachers in both content knowledge and instructional practices can build teacher self-efficacy (Nadelson et al., 2012). Teachers develop a level of comfort in their teaching by building their content and instructional knowledge. The teachers are more likely to teach subjects they are comfortable with, and both initial training in their preservice education as well as ongoing training during their careers are necessary to increase the teachers' level of knowledge. Teachers also benefit from seeing models of effective teaching (Nadelson et al., 2013). Building a teacher's self-efficacy is an important step in integrating new curriculum (Unfried et al., 2015). Co-teaching allows teachers to be present for lessons they are not comfortable teaching while watching a more confident teacher leading the lesson.

Review of Methodological Issues

Many of the studies that were examined for this review were found to be mixed-methods studies, with a few qualitative in design. One study was a quantitative study that assessed student achievement after the teacher had participated in STEM integration professional development, and was a section of a larger, longitudinal study that was being conducted simultaneously (Cotabish, Dailey, Robinson, & Hughes, 2013). The education field is a very complex field, one that cannot be studied by a single research method (Ponce & Pagan-Maldonado, 2015). Case study research still uses a variety of data sources to corroborate findings (Yin, 2018). Using multiple data sources provides validity for the study as well as a thorough understanding of the case being studied (Yin, 2018).

The studies examined for this review also often used a quasi-experimental design, often with a nonrandomized control group. Researchers could not randomly select students for classes as in true experimental research. However, quasi-experimental research still uses treatments, outcome measures, and experimental units, much the same as experimental research does (Teddlie & Tashakkori, 2009).

Sample size is often a concern in STEM integration studies and many of the studies researched on the topic were based on small samples. Becker and Park (2011) attempted to conduct a meta-analysis but reported that their findings should be regarded as preliminary due to the lack of empirical studies available on the effect of integrated STEM education on student learning. While meta-analysis often has a goal of synthesizing data, it can also identify weaknesses in the literature (Becker & Park, 2011). One weakness in the effect of integrative STEM on student learning is a lack of empirical studies. Gresnigt et al. (2014) also attempted to conduct a meta-analysis but had to change to a review when not enough articles could be found. Another limitation is the lack of uniform assessment to measure STEM learning at the young elementary level (Yoon et al., 2014).

The present study will fill in some of the gaps that occur in the current research base. There are few studies about STEM in elementary grades and not many examine student achievement alongside teacher perceptions, as did Moore et al. (2014) in a multiple-case study design. Yoon et al. (2014) utilized a quasi-experimental study design with a nonrandomized control group to study integrating engineering education in grades two through four. Their study looked at student achievement and found the students of teachers who integrated curriculum, and received support for the integration, made significant improvement on the pre-test and post-test

Moore et al. (2014) and Yoon et al. (2014) in separate studies looked at teachers who were implementing integrated STEM lessons for the first time at the upper elementary to lower middle school grade level. Findings from these studies revealed that teachers were willing to implement integrated STEM lessons and units, but they did not know how to do it effectively, even after professional development was conducted. The process of learning how to integrate STEM education effectively into classrooms requires teachers to create curriculum and/or teach curriculum in a way that is different than what they are doing now, and therefore will require more than one series of professional development to achieve the desired results. Both studies included small sample sizes and researchers were therefore not able to generalize the results.

However, small samples still provide information that other educators can use when attempting to integrate STEM education for the first time.

Synthesis of Research Findings

All students need to have some understanding of STEM subjects, regardless of career path (Honey et al., 2014). However, the current education system is not producing enough students who are interested in studying STEM subjects or in pursuing STEM careers (Sadler et al., 2012; Schmidt & Fulton, 2016). Exposing students to STEM during the early years of their education is essential to developing their interest (Nadelson et al., 2013). During their early education years, young children can learn foundational STEM skills (Aldemir & Kermani, 2016). Developing their interest and skills at this young age increases the likelihood they will pursue STEM courses and careers (DeJarnette, 2012; Moore et al., 2014; Sadler et al., 2012; Schmidt & Fulton, 2016).

To develop interest in STEM subjects and careers, students need to experience science and be actively engaged in lessons (Krajcik, Czerniak, & Berger, 2003). Integrating STEM subjects improves students' interest in learning and can increase interest in STEM subjects and career fields (Becker & Park, 2011; Sanders, 2009). However, there are very few curriculum programs for teachers to use to integrate STEM curriculum in the elementary years.

Teachers need training not only in the content areas of STEM, but in integration as well. There is a lack of guidance on how to integrate STEM into the curriculum (Guzey et al., 2016). When teachers do create their lessons, they fall short of true STEM integration (Moore et al., 2014). Current research does exist on STEM integration, however, this is mainly aimed at the secondary level. Therefore, a gap in STEM research exists, with few empirical studies available at the elementary level (Becker & Park, 2011).

Fully integrating STEM education is a massive undertaking that is not going to occur quickly and easily (Williams, 2011). Bybee (2010) suggested starting small and taking just a section, or a unit, or a lesson, and turning it into an integrated STEM study. Not only does this method provide the teacher with a realistic starting place, but it enables the teacher to go back to her comfort level as she processes her experience. There is a lack of literature on the affect integrated STEM education has on student achievement and especially on STEM education in the younger years (Becker & Park, 2011).

Integrated STEM education is a topic that is receiving national and even global attention, however, STEM subjects are not the focus of instruction in the early elementary settings. DeJarnette (2012) states that the elementary years are a prime time for creating interest in STEM subjects. Taking STEM classes during the elementary years also builds a student's confidence and ability, making it more likely they will continue in the STEM subjects in secondary years and beyond (DeJarnette, 2012). Before that can occur, teachers need more education and training on how to successfully implement all four STEM subjects (Moore & Smith, 2014).

Critique of Previous Research

Even though several studies indicate support for early learning in STEM (DeJarnette, 2012; Moore et al., 2014; Nadelson et al., 2013; Sadler et al., 2012; Schmidt & Fulton, 2016), there are few studies about STEM in elementary grades (Becker & Park, 2011; Gresnigt et al., 2014). Elementary school is found to be the ideal time to develop student interest in the STEM fields (DeJarnette, 2012; Moore et al., 2014; Sadler et al., 2012; Schmidt & Fulton, 2016). In early elementary, students are naturally curious and like to explore topics. This natural curiosity can be nurtured and developed to create students that are inquisitive and not afraid to experiment until they find the right answer.

There is also a lack of empirical studies on the topic of integrated STEM. For example, Becker and Park (2011) attempted to conduct a meta-analysis but reported their findings should be regarded as preliminary due to the lack of empirical studies available on the effect of integrated STEM on student learning. Gresnigt et al. (2014) attempted to conduct a meta-analysis three years later but had to change to a review when not enough articles could be found. Another limitation was the lack of uniform assessment to measure STEM learning at the young elementary level (Yoon et al., 2014).

Many studies discuss the lack of professional development in science for teachers and the need for more training in implementing integrated STEM and in developing the content knowledge in STEM subjects for K–12 teachers (Blackley & Howell, 2015; Capobianco & Rupp, 2014; Roehrig et al., 2012; Williams, 2011). Teachers who do not possess the appropriate content knowledge are often not comfortable enough to teach the subject (Yoon et al., 2014). According to the literature, there is a link between a teacher's content knowledge and effectiveness in teaching a subject (Nadelson et al., 2012). Teachers are more likely to make a change in their teaching when they see it modeled effectively (Nadelson et al., 2013). The literature also suggests that integrating STEM education at the collegiate level results in preservice teachers not only experiencing integrated STEM as a model, but also results in increased content knowledge and competence (Murphy & Mancini-Samuelson, 2012).

To use inquiry learning effectively, teachers must have strong knowledge of content, pedagogy, and theory (Ramnarain, 2014). STEM lessons utilize inquiry-based learning, as this is a primary example of how real scientists go about solving problems and making discoveries (Abdi, 2014). Inquiry-based learning also helps students understand how things work in the real-world and that they must be able to think and solve problems (Wang et al., 2009). Although problem solving is not explicitly written into STEM education, it is a common element in STEM education curriculum (Honey et al., 2014).

Even though evidence shows that students with integrated curriculum perform better than those with standard curriculum (Sanders, 2009), it is hard to enact educational reform. Full integration requires taking a new approach to teaching that is not familiar to some teachers (Williams, 2011). Further research on the impact of integrated STEM at the elementary level is necessary to build a database of empirical research. The research can guide leaders to develop an integration plan that is best suited to the needs of their students and teachers.

Chapter 2 Summary

In this chapter, the existing literature for integrated STEM and PLTW was examined. NGSS have been developed and, alongside many federally funded initiatives, are leading education toward an integrated approach. NGSS include engineering concepts, which is not a content area that is common in science standards. With national standards that are available for school districts to adopt, the focus is now on the practical implementation of how to integrate STEM subjects at a young age.

Integrated STEM curriculum requires teachers to change the way they teach; from a silo approach with each subject separate, to an integrated approach with the subjects taught together. Teacher training is required both in STEM content knowledge as well as in how to effectively integrate STEM subjects to achieve true integration of all four subjects. Integrated STEM utilizes engineering design processes to solve real-world problems and allows students the opportunity to develop their own solutions.

PLTW meets some of these needs by providing built-in teacher training and a curriculum that integrates all four subjects. It is a research-based curriculum that provides support to teachers through training before implementation and throughout implementation. It is a resource that is available to teachers in the district being studied, although not all teachers and schools have access to this resource. For those schools that do have access to the curriculum, there are only a few teachers that are implementing the PLTW curriculum. The present study was designed to explore the reasons why implementation is not more widespread by examining teachers’ experiences with implementation. In Chapter 3, the methodology used and the explanation of how the study was conducted will be discussed.

Chapter 3: Methodology

Employers are having difficulty filling STEM jobs due to a lack of qualified candidates. It is estimated that by the year 2024 there will be a shortage of 1,100,000 STEM workers in the United States (Varas, 2016). The reason for this lack of workforce-ready candidates is that students are not choosing STEM as a career path and therefore not providing the United States with a career-ready workforce. For students to pursue STEM careers, there must first be interest in STEM subjects in school (Sanders, 2009). To increase the number of students who pursue STEM careers, interest needs to be developed before the students enter high school (Tai, 2012).

Integrating the four STEM subjects leads to students developing a deeper and broader understanding of each topic and how the subjects work together in the real world (Moore et al., 2014). PLTW curriculum is an example of integrated STEM curriculum. PLTW is a curriculum model that requires intensive teacher training before providing access to integrated STEM content. This curriculum incorporates integrated STEM education while providing students with the opportunity to engage in and solve real-world problems (PLTW, 2014). Through a problem-based approach, students are led through activities that increase their knowledge of a topic. Students apply this knowledge to solve a hands-on problem at the end of the unit. PLTW is a promising program for integrating STEM curriculum into instruction (Roehrig et al., 2012).

This case study was designed to investigate the implementation of PLTW curriculum in first grade classrooms based on teachers' perceptions of the program's effectiveness, teachers' levels of self-efficacy in teaching science, and student achievement at the end of the unit. The case study methodological approach for the study will be covered in this chapter, as well as the instrumentation used for each area of the study: survey, interviews, and student assessment. Data collection and data analysis procedures for each area are also clearly defined.

Research Questions

The research questions for the study are:

1. What are the teachers' perceptions of PLTW's instructional strategies and effectiveness for science instruction as opposed to instruction using the district curriculum?
2. What are the experiences of the media specialists in working with teachers to implement PLTW? What are the media specialists' perceptions of student engagement and receptiveness to the PLTW curriculum?
3. What are the teachers' perceptions of student achievement following implementation of the PLTW curriculum?
4. What was the difference in mean scores in the level of self-efficacy for the first grade teachers who have taught PLTW and for those who have not?

Purpose and Design of the Study

The purpose of this case study was to investigate the implementation of PLTW curriculum in first grade classrooms based on teachers' perceptions of the program's effectiveness, teachers' levels of self-efficacy in teaching science, and student achievement at the end of the unit. Case study research is used to explore a real-life system using multiple sources of information and when controls are not placed over the behavioral events as part of the study (Creswell, 2013). Conditions that should be considered when choosing a research method are the form of the research question, the control that is required over behavioral events, and whether the focus is on contemporary events or not (Yin, 2018). Case studies are identified by their use of multiple sources of information and reports from a real-life system, either a single case or a multisite study (Creswell, 2013). The selection of a case study approach is also based on the unit of analysis and the object of the study (Merriam & Tisdell, 2016). A case study allows a researcher to choose any aspect of the data as a point of interest to study (Zainal, 2007).

In the present study, only one program implementation, PLTW, was explored in four first grade classrooms via interviews, a survey, and assessment results. A case study approach was selected to investigate the implementation of PLTW curriculum in first grade classrooms based on teachers' perceptions of the program's effectiveness, teachers' levels of self-efficacy in teaching science, and student achievement at the end of the unit. A case study approach was chosen for the present study because case studies provide in-depth analysis and descriptions of a system (Merriam & Tisdell, 2016). Case studies also focus on what is happening in the case and data collection is conducted to look for patterns (Yin, 2018).

In the present study, the case is the implementation of PLTW curriculum in the early elementary level. The research questions for this study are in nature, lending themselves to be answered by a case study. There is no control over behaviors that are necessary to answer the research questions. The research questions are designed to explore the behaviors that occur before, during, and after implementation of PLTW curriculum and look for patterns in the data. Based on the above criteria established in the research, a case study is the most appropriate method (Yin, 2018).

Study Site

The present study was conducted in a large school district in the Midwest. The town where the schools are located is neither suburban nor urban, rather it is a mixture of both. The public-school district serves over 18,000 students and has 21 elementary schools. Overall, the district had a minority population of approximately 40% for the 2016–2017 school year. A breakdown of the minority groups for the district overall and for each elementary school being studied is included in Appendix D. The graduation rate for the district increased from 86% in 2013 to 89% in 2016. The free and reduced lunch population (population that qualifies for lunch at a free or reduced price due to poverty) has risen from 39.7% in 2013 to 45% in 2016.

Study Population and Sampling Method

Purposive sampling was used to select the sample for the study. Criteria for the selection was simply willingness to participate in implementing PLTW's Light and Sound unit in a first grade classroom. In the district studied, all 76 first grade teachers were invited to participate. An email was sent to all first grade teachers in the district informing them about the study and asking them to participate. Due to lack of response, a follow-up email was sent to media specialists to inquire about teachers who might be interested at their school. Media specialists from two different schools responded. Four teacher from the two schools expressed interest only if their media specialist could co-teach the unit with them.

To be considered, the first grade teacher had to be willing to implement PLTW's Light and Sound unit in their classroom. The media specialists in the district were also contacted to identify teachers in their school who would be willing to participate. There were two media specialists who were willing to participate with their first grade teachers, and four first grade teachers willing to implement the curriculum. The teachers, however, were only willing to implement the PLTW curriculum if the media specialist was there to assist in the instruction of the units. The teachers who participated working in schools that had media specialists who were trained in PLTW curriculum and were willing to co-teach with their teachers. Only the four teachers and two media specialists that were willing to implement the unit were included in the study. All volunteers were requested to sign a consent form before participating in the study.

All first grade teachers in the district were invited to participate in the T-STEM survey to determine their science self-efficacy levels. The survey was sent electronically via an email link to all first grade teachers in the district. Three reminder emails were sent over approximately a two-week period.

Instrumentation

Three types of instruments were included in the present study. The interviews, T-STEM survey, and student PLTW post assessments are described below.

Interviews

Six semi-structured interviews were conducted with the teacher participants and media specialists who administered the PLTW curriculum. Questions were designed to guide the participants in a discussion about PLTW curriculum and how they viewed its effectiveness compared to their experiences teaching the same unit in the past using the district curriculum. Questions were also related to the research questions. The 40-minute interview consisted of five sections: background information, PLTW experience and training, student reactions and achievement, difference in PLTW and district curriculum in training and curriculum, and suggestions for improvement. The interview protocol was developed by myself and can be seen in Appendices A and B. Interview questions for the media specialists and teachers were validated by conducting mock interviews with an instructional coach as the expert. Based on their feedback, the interview questions were modified. A copy of the interview questions for the teachers and media specialists are in Appendices A and B.

Teacher Efficacy and Attitudes Toward STEM (T-STEM)

The T-STEM survey was created by TFI (2012). TFI is part of North Carolina State's College of Education, and their work focuses on advancing education through innovation and collaboration. The T-STEM survey contains seven constructs: a) personal teaching efficacy and beliefs in science and math, b) teaching outcome expectancy beliefs in science and math, c) student technology use, d) STEM instruction, e) 21st century learning attitudes, f) teacher leadership attitudes, and g) STEM career awareness (TFI, 2012). The present study only utilized the following two sections: personal teaching efficacy and beliefs in science, and teaching outcome expectancy beliefs in science.

The subscales of the T-STEM survey were developed in close alignment with the Science Teaching Efficacy Belief Instrument (STEBI) developed by Riggs and Enochs (1990). STEBI was established to help teachers identify their beliefs about teaching math and science to improve not only the time spent instructing, but the quality of the instruction as well. A Likert scale was used for each question to determine whether teachers strongly disagreed, disagreed, neither agreed nor disagreed, agreed, or strongly agreed with each statement. For analysis, a value of one was assigned to strongly disagree up to five for strongly agree. Each of the subscales of personal teaching efficacy and beliefs, and teaching outcome expectancy beliefs were averaged per participant. The science teaching efficacy and beliefs subscale had eleven items and the science teaching outcome expectancy subscale had nine items, making the survey 20 questions long. In addition to these 20 questions, there were demographic questions included in the survey to identify the length of time the teacher had taught and their background in teaching science. The higher a teacher scored on the survey, the more likely they believed that their science teaching affected student outcomes. Reliability was established for each subsection of the instrument using Cronbach's alpha.

Student Science Assessment

Students who had received PLTW instruction took the end of unit (post) assessment provided with the curriculum. The assessment used was developed by PLTW in conjunction with their unit and has not undergone any reliability or validity testing. The objectives covered in the assessment were:

- Vibrating materials can make sound and sound can make materials vibrate.
- Objects can be seen only if they reflect available light or if they give off their own light.
- Placing different materials in the path of a beam of light may cause the light to spread out, separate into colors, bounce back, or magnify.
- Describe how we hear sound.
- Describe how we see objects.
- Describe what can happen when different materials are placed in the path of a beam of light.
- Discover the relationship between sound and vibration.
- Experiment and document results of placing a variety of objects in the path of a beam of light.

Students were asked what makes light and what reflects light, and students answered these two questions by circling pictures. There were two questions about how sound is made, which were answered by the students circling the correct words for their choices. The next question was about the role light plays in how we see, with students circling words from two choices for their answers. The final question asked them to circle the picture that accurately represented how we see objects. The assessment was read to students to ensure their reading level did not hinder their ability to convey their understanding of the science.

Data Collection

Several different sets of data were collected for the present study. The teacher participants and media specialists who utilized the PLTW curriculum participated in an interview to gauge their perceptions on teaching PLTW versus teaching using the district curriculum. The T-STEM survey administered to measure the self-efficacy in teaching science and science teaching outcomes expectancy. In addition, teachers who used the PLTW curriculum administered an end of unit assessment to their students that was summarized using descriptive statistics.

Interviews

I recruited four teachers who were willing to implement PLTW's Light and Sound unit in their first grade classroom. Each of the teachers worked with their media specialist to implement the PLTW curriculum. The media specialists are the ones who have received specific training through the PLTW program and work with the classroom teacher to co-teach the unit. Purposive sampling was used and the criteria for the sample selection included seeking teacher volunteers from a variety of schools in the district and who have agreed to teach the PLTW curriculum.

A 40-minute semi-structured interview was conducted with the participants who were teaching the Light and Sound unit utilizing the PLTW curriculum. The interviews were conducted at the end of the Light and Sound unit as the semi-structured questions were designed to explore the teachers' experiences in implementing PLTW. The interviews were recorded using an audio recording app on an iPad. At the end of the interview, the recording was exported to a Google drive folder. From there, it was uploaded to a website called VoiceBase, which provides free transcription via machine and has a very fast turnaround time. Within a few hours, a machine had transcribed the interview into a big block of text, and an email was sent to me telling me that the transcription was complete.

I then listened to the interview while reading the transcript to ensure the copy was accurate. The transcription was sent back to the interviewee for member checking. Interviewees were asked to complete their member checks within five days. Both an iPad and an iPhone were used to record the interview for back-up purposes using password protected programs. The interview was a standard open-ended design as the questions were written ahead of time (Teddlie & Tashakkori, 2009). The interviews addressed the first two research questions as the questions were written in relation to the research questions.

T-STEM Survey

The T-STEM survey was sent to all first grade teachers in the district to provide a baseline for evaluating teacher self-efficacy in the district. Teacher participants in the present study were also given the opportunity to take the T-STEM survey that was developed by TFI, as part of North Carolina State's College of Education (TFI, n.d.). The T-STEM survey measures a teacher's confidence and self-efficacy in teaching science and math, as well as 21st century learning skills, leadership, and STEM career awareness by using separate questionnaires for each topic (TFI, 2012). For the present study, participants were only given the survey questions that measure their self-efficacy and outcome expectancy in teaching science.

Surveys were distributed to all first grade teachers electronically via an email link. A reminder email was sent out after one week and another reminder sent out after approximately two weeks. At the close of the survey, 49 teachers had participated, with all four of the teacher participants who were implementing the PLTW curriculum included in that number. Qualtrics software was used to assure anonymity as the software does not require a teacher to submit any identifying information when they complete the survey. However, in the survey, there was a question that identified whether the teacher taught the Light and Sound unit using PLTW or not. Teachers who administer the PLTW curriculum would answer yes to this question, and thus identify themselves in order to compare the scores between those that implemented PTW curriculum and those that did not. The self-efficacy survey answered research question four.

Student Science Assessments

Directions were sent out via email asking the teachers and media specialists to implement the unit with fidelity and to administer the assessment included with the PLTW curriculum upon completion of the unit. A copy of the assessment as well as the grading key were sent via school mail to the participants. Teachers then graded the students' assessments and entered the students' scores online through Qualtrics. A screenshot of the questions from the form is included in Appendix C. The assessment data partially answered research question three.

Identification of Attributes

Teacher self-efficacy is the belief a teacher has about his/her ability to promote student learning (Mojavezi & Tamiz, 2012). Teacher self-efficacy is influenced by a teacher's own experience in the classroom, student achievement, and observing other teachers' classrooms, among others (Holzberger et al., 2013). The interviews included questions that were designed to help teachers reflect on any changes in self-efficacy because of teaching the PLTW curriculum.

Data Analysis Procedures

Interviews

Open coding was conducted on the data. Open coding refers to the process of reading through the transcripts and summarizing the responses (Burnard, Gill, Stewart, Treasure, & Chadwick, 2008). Then, axial coding occurred, with the codes being examined for duplicates as well as connections between the codes (Kolb, 2012). Axial coding is the stage of coding that takes the data developed from the open coding phase and makes connections and develops themes. It is during this stage that the data themes and categories are combined into a smaller number of categories. After this is completed, the new list of combined codes was used to categorize the data and develop themes, which is often done by marking the transcripts in different colors (Burnard et al., 2008).

T-STEM Survey

Participant surveys were accessed online and scored electronically. The results were analyzed using descriptive statistics as suggested by TFI (2012) in their documentation. TFI (2012) recommended assigning a number value to each response, then averaging the section. This number value will show how much a teacher believes their actions affect student learning. The higher the number (up to five), the stronger the belief. Each subscale is computed as an average for each participant. Descriptive statistics were used to analyze the data. The averages from each subscale were grouped and compared, such as those that taught PLTW and those that did not. Results will be shared in Chapter 4. The results of the survey were evaluated to see whether there was a trend in the scores for teachers who teach the PLTW curriculum.

Student Science Assessment

Participants who taught PLTW curriculum were asked to administer a pre- and post-test assessment to their students and submit the scores to myself to be entered into an Excel spreadsheet for analysis. The end of unit assessment was provided with the PLTW curriculum and it has not undergone any reliability or validity testing. Descriptive statistics were used to summarize the data and a table developed to display the results.

Limitations and Delimitations of the Research Design

One of the limitations of the study is selection bias. Participants determined whether they were interested in teaching PLTW curriculum or not, and I did not assign the participants to groups. This can work to the advantage of the study, however, because if the participant has chosen to implement the PLTW curriculum, they will be vested in the curriculum and will work to implement it correctly throughout the time and length of the study. The final group for the interview and the survey were those that chose to participate, making the final sample a purposive convenience sample.

The student assessment that was used was one that was provided with the PLTW curriculum. At the time of this research, an assessment that has been validated and found reliable could not be found.

Another limitation of the study is that it was only administered at a single site. Only teachers in one school district were studied, although the teachers were at two different schools. Finally, the study used a small sample size. These two limitations do not allow the findings to be generalized to the general population. Case studies, in general, have the same limitation. Each study is unique to the situation being examined and cannot be replicated exactly as it was studied (Harland, 2014). However, the theories that case studies generate can be used to further develop and analyze the program and procedures being studied (Yin, 2018).

Validation

Credibility and Dependability of Data

Interview questions were validated by conducting mock interviews with an instructional coach as the expert. Based on the feedback, interview questions were modified. Member checking was used to ensure validity in the interview process. The member checking process has been identified by Stake (1995) as one that is necessary for case study validation. At the end of the interview, the conversation was transcribed through the VoiceBase website, the transcript was cleaned by myself and sent to the teacher participant for approval. This data quality check is powerfully important because it ensures that the researcher has interpreted the participants' perceptions accurately (Teddlie & Tashakkori, 2009). Using multiple data sources allows for triangulation of the data, increasing the credibility (Teddlie & Tashakkori, 2009). The data sources for the present study were the student achievement scores, the teacher survey, and the semi-structured interviews.

Reliability for the T-STEM survey was measured with Cronbach's alpha by TFI. Surveys by TFI were administered to 257 science teachers, 72 technology teachers, 17 engineering teachers, 120 math teachers, and 218 elementary teachers (TFI, 2012). After a factor analysis and feedback was received, four questions were removed and others were reworded. Items were also reworded to reflect positive wording as well as changing student achievement to student growth (TFI, 2012). Cronbach's alpha computes the correlation of items in an internal consistency analysis (Adams & Lawrence, 2015). A score of 0.70 or higher is considered acceptable. Cronbach's alpha for the elementary science subsection in the TFI (2012) study was 0.905 for personal teaching efficacy and beliefs.

The assessment that was administered is an end of unit assessment developed by the PLTW developers specifically for their curriculum. The validity and reliability of the measure has not been determined. It was developed with the curriculum to assess students' knowledge at the end of the unit. PLTW developed the summative assessment to be specific to the knowledge and skills gained in the unit that can be assessed through multiple/choice and constructed response (P. Irwin, personal communication, September 27, 2017).

Expected Findings

It was expected that participants who implemented the PLTW curriculum would have a higher self-efficacy in science than those who implemented the district curriculum. During the interviews, I expected to hear teachers discuss their lack of time when attempting to include science instruction in their classrooms. I also expected the participants to express knowledge about the importance of science instruction. When PLTW was discussed, I expected the teachers to be hesitant to implement this curriculum on their own as all participants taught the unit with their media specialist.

Ethical Issues in the Study

To ensure confidentiality in the survey process, names were not identified and real names were not used. Instead, the participants were coded as T1, T2, T3, T4, MS1, and MS2. Participants were asked the T-STEM survey questions, as well as whether they participated in PLTW curriculum or not. This question was presented to analyze student achievement scores of classrooms that participated in PLTW curriculum with the self-efficacy score of the teacher in that classroom.

Teachers that participated in the interview were provided with a consent form as well as information about how to quit the study without penalty if they wanted to. Due to the small size, it is possible the participants could identify themselves and their peers in the study. Therefore, codes were created for each teacher and media specialist to protect their identity.

I conducted a conflict assessment, with no financial conflict found as the study was not funded nor was there any compensation offered to participants. Researcher bias was not substantial. Having participated in the PLTW training, I understood how powerful the curriculum could be when implementing integrated STEM education. I also thought the training for the media specialists was compulsory and beneficial and was surprised to discover that one of the media specialists had not participated in the full training course. There was no safety concern for the individuals participating.

The benefits of this research will aid the district when PLTW curriculum is considered in future school years. The results will be shared with them and will provide administrators with honest feedback about the program. Then, decisions can be made on the most effective method for delivering science and STEM education.

I received the physical copies of the student assessment with the names of the students removed. These copies will be kept in a locked cabinet for three years and then destroyed. Approval to conduct the present study was granted by the participating school district on November 2, 2016 with an addendum approved on February 8, 2017 and an extension granted on May 19, 2017. A final extension was granted on October 31, 2017. Concordia University's IRB Board approved the study on June 20, 2017.

Chapter 3 Summary

The methodological approach for the present study was discussed in this chapter. A case study approach was used to investigate the implementation of PLTW curriculum based on teachers' perceptions of the program's effectiveness and their levels of self-efficacy in teaching science. Multiple sources of data were collected for this case study including interview data, survey data, and student achievement data. The themes obtained from the interview data were developed via the coding process. Trends in the student achievement data and the self-efficacy data were examined. Finally, the data were triangulated to substantiate the findings. In the next chapter the results from the study are presented and summarized.

Chapter 4: Data Analysis and Results

This case study examined the perception of teachers concerning the implementation of the PLTW, which is an integrated curriculum, and the integration challenges that teachers encountered. As part of the study, four teachers volunteered to teach a PLTW Light and Sound unit with the assistance of a media specialist. Data was collected from three sources: interviews with teachers and media specialists, the T-STEM survey, and a PLTW student assessment. The T-STEM survey was designed to measure the self-efficacy and confidence of teachers related to teaching science. Descriptive statistics were used to analyze the findings from the T-STEM survey received from first grade teachers in the studied district and the PLTW student assessment data. This chapter includes a description of the sample, describes the method used for coding the interview data, and presents the findings.

Research questions included:

1. What are the teachers' perceptions of PLTW's instructional strategies and effectiveness for science instruction as opposed to instruction using the district curriculum?
2. What are the experiences of the media specialists in working with teachers to implement PLTW? What are the media specialists' perceptions of student engagement and receptiveness to the PLTW curriculum?
3. What are the teachers' perceptions of student achievement following implementation of the PLTW curriculum?
4. What was the difference in means in the level of self-efficacy for the first grade teachers who have taught PLTW and for those who have not?

Description of the Sample

Four first grade teachers and two media specialists from schools in the studied district participated in the study. All six participants were female. There were three teachers from one school and one from another school in the district. The media specialist from one of the schools was named MS1 and the media specialist from the other school was named MS2. The teachers were named T1, T2, T3, and T4. Teachers code named T1 to T3 attended the same school. The pseudonyms were created for the teacher and media specialist participants to protect their identities. Table 1 summarizes participants' years of experience. Current years for the teachers refers to how many years the participants had taught first grade at their current school and total means the total number of years of teaching experience. Current years for the media specialists refers to how many years they have been a media specialist in their current school.

Table 1

Years of Experience

Participant	Years at current school	Total years teaching
MS1	5	30
MS2	2	26
T1	1	16
T2	4	14
T3	24	32
T4	2	18

Both media specialists have many years of experience. MS1 is in her 5th year as a media specialist, and she will retire at the end of this school year after completing her 30th year of teaching. MS2 is in her 26th year as an educator, and this is her second year in her current position. MS2 has served as a media specialist in the past, both in elementary and middle school.

T1 is in her first year of teaching first grade. T2 is in her 14th year as a teacher and has had a varied background. She has taught upper elementary at different schools in the district being studied, four years in another state, and has taught at the university level. T3 is in her 24th year at her current school, with all those years in first grade. She taught at a different school for eight years prior to that. T4 is in her second year in first grade at her current school. She taught second through fourth grades for 16 years prior to that at a different school.

The T-STEM survey was emailed to all first grade teachers, with three reminders sent out over the course of two weeks. There were 49 teachers that completed the survey. The T-STEM measured the self-efficacy of the first grade teachers in teaching science and was used to determine the level of comfort that existed in first grade teachers in the district. This was used to triangulate the data from the interviews and the student assessment data by showing that teachers are confident in their teaching, and their students are proficient in their learning. The interviews used this data and expanded on it, showing that teachers know that science is important and they want to teach it, but they are frustrated with the curriculum choices from the district.

Research Methodology and Analysis

The case study method was chosen because education is a complex field and case study research allows for that complexity (Hamilton & Corbett-Whittier, 2013) as it allows a researcher to look at a particular case, or bounded system, to determine what is happening without interfering with the way the system currently functions. For the present study that was the implementation of PLTW (Stake, 1995). Many data sources of data are used in case studies, which include both quantitative and qualitative data (Merriam & Tisdell, 2016). Multiple data points allow for a more in-depth and deeper understanding of the bounded system being studied (Hamilton & Corbett-Whittier, 2013). Descriptive statistics were used to determine the mean and standard deviation of the student achievement data and the teacher survey results. Interviews were coded and analyzed for themes.

Six interviews were coded using inductive and open coding procedures. The transcripts were first loaded into qualitative analysis software. Inductive coding uses the data to develop the codes and themes (Burnard, et al., 2008). Open coding refers to the process of taking each transcript and making notes about what is being communicated in the text (Burnard, et al., 2008). The process is similar to the constant comparative method that combines coding and analysis in order to generate theory based upon the data (Kolb, 2012). The transcripts were examined multiple times and codes were adjusted as the analysis revealed the themes of the data.

The first time the transcripts were read, codes were created to organize the data. There were no predetermined codes used for this round of coding. Once all the transcripts were reviewed for the initial reading, the codes were examined to determine if any could be combined or renamed. Then, the transcripts were reviewed again considering the set of codes that were created to analyze the data for recurring themes. When this round of analyzing the data was complete, the codes were once again examined for duplicity and the transcripts were reviewed one final time.

Upon completion of the coding process, the transcripts were then organized through the ATLAS.ti qualitative software (version 8.1.3) and exported to Excel. Here, the transcripts were sorted by code, and then the codes were placed on separate pages according to the research question addressed by each code. This organization enabled me to view all the codes pertinent for each research question on one screen for analysis. The codes were also copied to a Word table that was organized by the themes that were identified during the coding process.

Deviations from Protocol

There were no deviations from protocol.

Summary of the Results

Teacher Interviews

16 themes were identified via the coding process. Codes were developed when the researcher read through each transcript and evaluated with the teacher was saying. The codes were then examined for similarities and common themes emerged. The themes that were identified through the teacher interviews were: curriculum adaptations, materials, developmentally appropriate, review of concepts, student achievement, transfer of knowledge, science background of teachers, and school/district implementation. The other eight themes were identified in the media specialist interviews.

Curriculum adaptations. There were parts of the lessons the teachers felt were missing, such as videos and reading passages. One teacher said, "Besides having hands on I would have more links to videos and things that you could watch that cover the same and reading passages you could have you know things that link into our reading." Another teacher felt the vocabulary needed more support.

> No I think it might have been helpful, too, if I was teaching it myself if they added that component of more support for the vocabulary. Whether it came with cards that we put up, or visuals like a key word, and then they see the key word, it would be a symbol of refraction or something and then their whole unit it's kind of going back to that. I feel like in this program quite a few times there's like this kernel of power and it just wasn't, it

> wasn't illuminated in the curriculum yet. Like, Oh you've got this great vocabulary, you're helping us engage with it and then we didn't really go very far with it. You know because, they're first graders because I think we had the potential to send them to second grade really have a foundational understanding of light and sound right and I don't know that we do. You know, better than they would have been in our old curriculum but still not clearly there.

One teacher was frustrated at the lack of access to the curriculum, and the fact that the lessons cannot be printed for planning purposes. She uses her media specialist's log in and has not explored the site extensively, but enough to know that she cannot print the lessons. She was able to work around that by copying and pasting a screenshot, but even that is limited. She found this very frustrating because she needs, "to see the end to know where I'm going I feel like it's not all there for me." The theme of curriculum adaptations was identified due to the number of comments the teachers made about the adjustments needed. These adjustments are ones that teachers can make, but it was noted during the interviews that these adaptations caused the teachers frustration and made the curriculum more difficult to implement.

Materials. There were many comments about the curriculum resources and the materials that are in the kits sent from PLTW. While the teachers and media specialists agreed that the kits that are purchased for the curriculum are nice, they also have a lot of room for improvement. One teacher stated, "I'm very interested in it it's just time and the reason why and I do like the program because everything was there all the materials were there and that was wonderful so I think I would be able to obviously do it on my own because it is very. You know it's packaged it's all there all the materials that's nice.". The same teacher also expressed frustrations with the materials, and that there had to be adjustments as the lessons were taught in order to compensate for the lack of quality or the lack of quantity.

She also had some advice on materials management: “just make sure you have your materials out ahead of time because there were a few things that we had that looked similar” and it was hard to determine which materials were to be used for which activity, especially with the students waiting. Another teacher shared some advice as well on how to manage the materials for the lessons, which was similar advice of having the materials out and ready to go.

One of the teachers had many comments on the materials. She felt PLTW had great lessons and potential, but felt that the quality of materials did not match that potential. She felt the tools were poor and did not always work great, though she did like the hands on work that the materials were designed for. She also said the felt there was lots of good language, but the “materials seem to be limiting, big time because it really, it was like powerhouse potential and we’d get to these puny little materials I was like frustrated” with the behaviors that would occur with her class while they waited on their turn for the materials. She commented that she would be willing to teach this unit again if the materials were improved.

Developmentally appropriate. There was some discussion on the appropriateness of the curriculum in relation to first graders and their development. The teachers found they needed to add components to the curriculum, or adjust the tasks in order to meet the needs of their students. Two of the teachers discuss the vocabulary in the lessons and how they felt this was an area that could be improved. They both liked the fact that the correct terms were used, such as transparent and translucent, but neither of them felt that the curriculum provided students the tools they needed to help the students understand what those terms meant. One teacher suggested,

> cards that we put up, or visuals like a key word, it's refraction and then they see the key word for, it would be a symbol of refraction or something and then their whole unit it's kind of going back to that. I feel like in this program quite a few times there's like this kernel of power and it just wasn't, it wasn't illuminated in the curriculum yet. Like Oh you've got this great vocabulary, you're helping us engage with it and then we didn't really go very far with it.

There was some advice was shared on the timing of the curriculum in the first grade year. One teacher commented that while the curriculum was appropriate for first grade, she would not recommend teaching it during the first half of the year as the writing requirements would be too hard.

Review of concepts. The teachers had the following comments about the story theme that is used throughout the lesson. PLTW units start with a story and a problem. The students work through lessons to learn the content they need, then design their own solution to the problem. The teachers often refer to it as spiraling, but the content in the unit does not spiral. The curriculum uses the story to maintain interest in the lesson.

> I liked the story; it was the sound and sight unit; and the story at the beginning seemed to be engaging for the kids. I wish it would have come back to maybe a few more times instead of just at the end. Because I'm not sure that they really remembered a lot. Because we didn't do it every day, you know, we only did it like twice a week and for four weeks or whatever. We had lots of days off, I mean so it was just kind of ... if they

> would have reviewed and brought the lesson back around to the story every once in a while, that might have been helpful to the kids.

Though the term spiraled is used here, it actually is not the content spiraling. The problem that is introduced at the beginning of the unit presents the students with a problem that needs to be solved. In the light and sound unit, the three characters in the story are stuck in the woods and they can only communicate through light and sound. The unit progresses along, teaching the kids about concepts that will help them solved the problem. At the end, they revisit the problem and are given materials to generate their own solution.

They also commented on the fact that the curriculum does not have built in review. The lessons build upon the previous lessons, but they do not go back and reteach or revisit the concepts that were taught. Two of the teachers specifically mentioned that they would like to have seen the curriculum review the topics before they moved on.

Student achievement. Student achievement was a theme that was discussed by looking at the typically high-achieving students with the typical low-achieving student.

> I would say it was interesting to see some of my EEE (the gifted program) friends that are you know labeled for their giftedness and creativeness and they were more so my friends that were less likely to get started because they wanted to have a direct, answer to the question. Where they were in our projects (we had to figure out how to get out of the woods using a bunch of different materials) there was no right or wrong answer but the flexibility and thinking with some of my higher, that should have been my higher level thinkers was interesting. And some of my lower level thinkers were able to pick up the materials explore and play with them and figure out what they were going to do and they just made up a plan and they had some great ideas.

There was not anything that stood out to this teacher, though she does state that her strongest student in science did not get it, while others that have less background knowledge did.

> You know actually kind of all over. I noticed it was my, what I would consider my strongest student in science, has a lot of background knowledge, didn't get that. But some that didn't have background knowledge, got it. Yeah my guess is that well we also had issues with kids, because this was drawn out for so long, we definitely had kids that missed days. I don't think we did much, going back and reviewing and you know checking and that sort of things.

This teacher saw growth in her low achieving students that she had not seen during that school year. She said these two students have struggled all year to retain information, yet were able to answer questions about the material in the PLTW lessons. She felt that it validated the exploration aspect of the lessons.

> I feel like some of them that have difficulties retaining stuff and they'll say, oh its waves. So yeah I think I've had a couple surprises. It kind of reaches kids... Yeah it reaches them in different ways. I don't know that it changed a lot about what I did last year. It might change some things this year just because I have seen a couple students that have had more difficulty retaining things and they are paying attention to things that have stuck with them so. It maybe gives more validity to that kind of crazy exploration time where it almost feels out of control but maybe something is coming out of that.

Transfer of knowledge. One teacher discussed the transfer of knowledge she experienced with her class. These students noticed her glasses refracting light during a reading group outside of their science time.

I think it did. Actually, and when we were back in the classroom it looked, things would come up you know about a reflection or why would that be. One day I took my glasses off when I was working with a child for a second and for some reason, you know we had like a little light shining through it was like green on my white paper and they were like, Whoa. And I was like, look at that and before this project with they would never, I wouldn't even have noticed it. I thought that was good that we were able to talk about it and figure out what that was.

Science background of teachers. This theme was identified as the teachers discussed their backgrounds in science training. Most of them did not have extra, or specific, science training. But one teacher did discuss her previous training and how it helped her comfort level when implementing PLTW with her first graders.

When I first started it was when science was on the state test in third grade and it was the beginnings of the state test and so I was pulled out several times for half day trainings on the science unit. Now it's like this lesson, it's on the computer so it's very different. I remember a whole half day of training over the plant unit and a half day training over disease, so it's very different.

I like the sound stuff better just because third grade had it and I taught the sound stuff for years and so I feel like I am more knowledgeable about it. You know I just feel more competent and like I've got way more knowledge than light. We didn't really teach light before so I'm just learning with them.

School/district implementation. There were just a few comments about how PLTW is implemented in the district. Project Lead the Way has been available in the district for several years, but is still not widely implemented nor is it available to all teachers. One teacher kept mentioning that she felt that PLTW was a big secret, and not one that was shared with everyone in the district. She felt that if it was more widely known, that if teachers were hearing other teachers talk about how great it is, then there would be more teachers that were willing to implement it.

Media Specialist Interview

The following eight themes were identified through the coding process: training, materials, cost, exemplar lesson, working with teachers, developmentally appropriate, student achievement, and district implementation.

Training. The first theme was training. The two media specialists had different training experiences. Both felt that their experience was enough for them to be able to implement the curriculum effectively. Project Lead The Way had training videos that lead teachers were required to watch before the modules, which is what they call their curriculum units, were unlocked. According to MS2, that changed for this school year. She was no longer required to watch the videos before she was able to access the content. The website was very difficult to navigate as well.

MS1 participated in the three-day lead teacher training that was hosted by the district and PLTW a few summers ago. This is the training I also attended. MS1 is the media specialist that had implemented the light and sound unit the year before with her teacher. Their implementation for this study was the second time they had taught together.

> I went to PLTW training for 3 days. It was good because it was hands on. We actually got to work through some of the PLTW lessons/kits with the PLTW teachers. It was not a sit and get training which made a huge difference. It was helpful to understand that there are 5 main lessons, 3 that build the foundation, vocab and 2 that actually have

> students solve an authentic problem. It was helpful to understand the Design process too and have some familiarity with the lessons prior to teaching them. Hands on learning is vital!

Materials. The theme of materials was identified in the media specialists' interviews as well as the teacher interviews. The discussion centered around the management of the materials and how cumbersome it can be, as well as the ease of implementation when everything is sent in the kits that can be purchased. The cost of the kits was part of the discussion with the media specialists as well.

Cost. Though not discussed in depth, cost is a factor in implementing PTLW curriculum. The media specialists do have a budget they spend on their media center, and it encompasses the entire media center. Therefore, they are making choices about how to spend their budget on books, makerspace items, and PLTW kits.

Exemplar lesson. This media specialist discussed a kindergarten lesson. This theme was chosen as it shows how PLTW curriculum works from the viewpoint of a different grade level.

> Well, I really enjoy the human body one for kindergarten that has probably been my favorite unit because the kids get to see X rays. So in the kit it has all the little bones and they're supposed to make an outline of their hand and then they're supposed to place all of the bones on. That's one of the consumables, these little bones. So I took white paint and a Q. Tip and I have them do a dry run with the bones, and then we push those aside and then they paint on so I have kind of adapted that. But they really walked out of there, and then the design process piece was they had to make a cast. But there was a lot of other things you know before that too. But I felt like that project, the making of the cast was

> fantastic and they really understood what a broken bone was. They understood going through the process of really creating something, adjusting and fixing it. I really like the kindergarten units they've been my favorite. The straight up what is engineering one with kindergarten they have to build a house for the three little pigs, and then we blow it down. I think that's been a fabulous lesson.

Working with teachers. Both media specialists discussed their experiences working with the teachers. MS1 had taught this unit with her teacher the previous year, but MS2 had not implemented PLTW with her teachers in previous years. MS2 discussed her plans on changing her approach with her teachers in order to get buy-in from them and have them more involved in the curriculum. She would focus on co-teaching next year instead of her being the one that delivers the instruction.

MS1 has had a very favorable experience with her teachers and implemented PLTW lessons. She believes the reluctance to implement results from district pacing guides and the pressure to teach to those guides. She also does not feel there is enough time to plan properly for PLTW lessons for the teachers and the media specialists, and definitely not enough time for them to plan together.

Developmentally appropriate. The media specialists, like the teachers, identified times when they had to adjust the curriculum to meet the needs of their learners. It was usually a small adjustment that was necessary due to the age or the attention span of the students.

> Actually I have found the PLTW lessons I have done pretty awesome! Often we tweak a few things in the lessons to fit the needs of our students. Example, we may read additional stories or provide videos to support the PLTW foundational information.

It is very helpful that most of the resources you need to teach the lesson are provided including videos, worksheets, hands on materials. Also, using the Design process embedded in each unit was helpful as well. I put the design process up with older students to remind them where we were each step of the way. I didn't do this with 1st grade as much, it was a little above their heads. We had to break it down. Also I provided more time for students to discover answers instead of me being the "knower of knowledge". This is so powerful!

Student achievement. Though the media specialists do not give grades, they know the students over the course of several years and therefore have a different view of the development of the students and their abilities.

I don't think so because. I don't want to say because I'm not surprised by them but I think it gives them definitely an opportunity to show their thinking in a way that doesn't always come through. For example, I had a kindergartner last year who is in first grade this year who is extremely intelligent and has such a creative little mind. He has a vision he can't make his vision happen. But through the process of last year and this year I could see his vision, I mean I could understand what he was trying to accomplish. And he's reading WAY below level he's writing way below level but there's definitely a lot of. Creativity and thinking happening and so that was really exciting but I'm not surprised by that. I think it's wonderful whenever you get kids an opportunity to show what they know in alternate ways but I don't know that it surprises me because I believe that kids often know more than what they're able to demonstrate.

District Implementation. Media specialists in the district have been tasked with implementing PTLW curriculum. They are not considered administrators, but are leading the lessons and organizing their time to teach with their teachers. Because there is no district policy, the implementation is different in every building.

Presentation of the Data and Results

Research Question One

What are the teachers' perceptions of PLTW's instructional strategies and effectiveness for science instruction as opposed to instruction using the district curriculum?

The teachers perceived the program with frustration, especially those that were implementing the curriculum for the first time. During their interviews, they were focused mainly on the materials and the frustrations with the quality and the management.

> OK my class and MS2 we enjoyed the Project Lead the Way program that we did with light and sound. Everything seemed to go well, however I was the first group that MS2 would send through so the lessons the way she started to present them we had some problems with just behaviors and first graders in the materials. So we had to step back and run them a little bit different: I know she had changed some things just because of the amount of materials that were out at times with first graders. But overall we enjoyed the program. I loved how the students were able to problem solve on their own and write about their thinking, play and discuss that was wonderful and one thing in our program, the only thing that I thought was above our level was refraction.
>
> Just make sure you have your materials out ahead of time because there were a few things that we had that looked similar. There are colored lenses that we were to put together and we were looking for what color was made when the two came together that was really difficult and we didn't always see the colors that the text said that we should see but there was also some other items in the material that look similar.

Let's see some of the strategies that I thought were helpful is probably, even though I did feel the tools were kind of poor they didn't always work great, I really like that they did have some real hands on tools for them to really use. So that was helpful and they were they definitely really enjoyed it and I liked the strategy of them having to come up with a plan before they try it out. So that was a really, I know they gain from that process.

If I did it again I would teach myself. We had some issues with that but. And if the materials were improved I would be open to teaching it again. Half way through it I probably wouldn't have said that but now that it's done, so I do think the classroom teacher being in charge at least in our situation would have been better.

I wish the materials had been. All they were like, they had the right idea, but they just weren't... Like the little things that were supposed to refract they didn't always refract very well. Because, you know, there are sixty kids using them and after a while they just seem to not work. Oh, and actually an odd thing with the flashlights, because it was kind of painful when it got in our eyes. And that was one thing, I think I know why they do that, because it's such a concentrated light. I wish Project Lead the way came up with something like an L.E.D. Light that was on the stand and you put things underneath. You can still move it but there's a little bit more control. And they were even trying not to but, it just, you know, like they'd be talking to me and all of a sudden I'd be Ahhh. So quite a few of the materials I just felt like, and I kind of wish there had been more because you know, asking six year olds to share one flashlight is hard, it's very hard. So we had to spend a lot of time teaching them how to wait. I wish it had been partner activities, as to sharing. I do remember those moments but I thought there's a lot of good language in it.

> Review, and I really think materials seem to be limiting, big time because it really, it was like powerhouse potential and we'd get to these puny little materials I was like frustrated. It was hard and so we had to kind of talk around it. And literally we had, we only had one bad day that, I left frustrated because we dealt with; I have a really sweet class and real attentive and real eager and they just were in trouble all the time and it didn't feel good. This is a curriculum issue, you know developmentally we need better and more materials we don't have them and so they were getting so frustrated. I'm getting frustrated, MS2 is, and I thought Project Lead the way, that's your problem right there. But other than that I do feel that it had high expectations for the kids, which I liked. The language was crisp and clean which I really like they're expected to learn these difficult words with. They thought it was fascinating, you know how kids are about science. You know that so yeah and they even with the limited materials they really enjoyed the day they got to try that the project you know to try to see what the came up and work to test, so that was good. I think just the materials and having the materials ready. We do it at the end of the day and so we've had lunch and we've had almost an hour and a half of instruction and stuff and then we've got a switch. And then all of us have to be ready and. And it's a transition that's closer to the end of the day which is difficult. Right so it's just, you know, having that out and ready and today it was like the flashlights aren't working, but we figured that out and it was fine but it was painful. It's a moment of panic right at the beginning where it's like oh my gosh, they're waiting and this isn't working.

The teachers had lots of problem keeping the materials organized and ready for the students when they taught the lessons. They also had issues with the quality of the materials, and felt that was an area that PLTW needed to improve. The issues with the materials created an experience that was not positive and left the teachers with frustrations. Once teacher did not that the kits do provide everything that is needed, which she found to be positive. “You know it's packaged it's all there all the materials that's nice.”

However, when they were able to move past that frustration, they found some positive aspects of the curriculum that they did like. “They definitely really enjoyed it and I liked the strategy of them having to come up with a plan before they try it out. So that was a really, I know they gain from that process.” T2 also discussed some changes she would make to the flashlight, in particular, but ended by saying, “I do remember those moments but I thought there's a lot of good language in it.

All of the teacher participants liked that PLTW curriculum starts off with a story about kids that ends with them kids having a problem that needs to be solved. “I liked the story; it was the sound and sight unit; and the story at the beginning seemed to be engaging for the kids.”

> It started with the problem that we were going to be solving the entire unit and then she touched back and it came up again like. Our third lesson together and it just kept spiraling and she kept adding on pieces and we kept exploring so I liked that and then at the end we went back to that same beginning problem and were given the materials in a different way, and I liked that.

T4 also discussed the story, saying, “I like it's got a continuous thread, like the story.” T2 stated, “I think having that problem at the beginning that we're trying to help these people, I think that made a huge difference in driving their interest and driving their learning I do think too it...” She ended with a discussion on how the story should be revisited often in order to help the students remember what they were working toward, “it would have been good to keep reviewing the problem because when we got to be end, all of them had forgotten.” T3 agreed, saying, “I wish it would have come back to maybe a few more times instead of just at the end. Because I'm not sure that they really remembered a lot."

T2 was the only one that spoke to the difference from the curriculum from the district and how it compared to PLTW curriculum.

> This felt definitely more planful, more intentional. The old ones, we don't do the old light and sound now as you know, any more with Mystery Science, but those felt to me more like, activities about light we're going to explore light and we're going to explore the light and we're going to explore sound but it didn't feel that because there wasn't any problem to solve, it didn't really matter

The teachers also discussed the adaptations they had to make, such as adding videos or reading passages (or their plans to in the future).

> Besides having hands on I would have more links to videos and things that you could watch that cover the same and reading passages you could have you know things that link into our reading.

One teacher mentioned adapting the assignments in order for them to be appropriate for the first graders, such as lowering expectations. T2 said, "I reduced my expectations as we went along and then it was it worked better. And I really liked that they did some good writing." T3 also discussed the timing of the curriculum during the school year, "I would definitely not teach that first semester because with all the writing they need to do I would definitely say that for second semester first graders."

Finally, there was some discussion on the vocabulary from the unit. The teachers felt the vocabulary was strong, but underdeveloped.

No I think it might have been helpful, too if I was teaching it myself if they added that component of, more support for the vocabulary. Whether it came with cards that we put up, or visuals like a key word, it's refraction and then they see the key word for, it would be a symbol of refraction or something and then their whole unit it's kind of going back to that. Just because it's I feel like in this program quite a few times there's like this kernel of power and it just wasn't, it wasn't illuminated in the curriculum yet. Like Oh you've got this great vocabulary, you're helping us engage with it and then we didn't really go very far with it.

I think that some of the materials like the, in one of the lessons it was transparent, translucent and they didn't really explain that. And I know the kids were supposed to explore and understand that. I think maybe if they would have given those words ahead of time translucent transparent and the other one...opaque. They may have looked for that a little bit more.

Research Question Two

What are the experiences of the media specialists in working with teachers to implement PLTW? What are the media specialists' perceptions of student engagement and receptiveness to the PLTW curriculum?

Media specialist have been tasked with implementing PLTW curriculum with teachers in the district being studied. Each building in the district being studied is at a different place in implementation. Some buildings have no implementation, while some have every grade level implementing at least one unit.

MS2 felt she had to proceed very carefully with her implementation as her first grade teachers had not had any experience with the curriculum before.

“I think well, I think. For me, it was an interesting, because they had not done it before so. I felt like I had to carefully introduce it, and try to get buy-in, really working trying to get buy in from them. I think they were pleased.

She also has plans on how she will change the way she approaches the teachers next year with implementation in order to create more of a team approach to teaching PLTW with first grade next year. She said, “I think I'd meet with first grade next year, I mean to approach it in such a way that is more on the co-teaching piece. Because some jumped in more than others.”

MS1 had a more favorable view of implementation. She has been implementing PLTW for the last few years, she could not remember exactly how many. MS2 has only been in her position for two years, and this was the first time she had implemented PLTW with her first grade teachers. MS1 said, “I think teachers have been very favorable with PLTW lessons. I think teachers would like to teach this way more often but feel the pressures of staying on pace with District curriculum.”

MS1 was more concerned with time, both to plan with the teacher and to implement the lessons.

> There is never enough time to collaborate with teachers to really develop the PLTW lessons. We are often flying by the seat of our pants, planning in drive by conversations at lunch or in the hallway. Planning time is huge and there is not enough of it!!
> This is a challenge mainly because teachers feel so much pressure to teach reading, writing and math. Those subjects seem to take priority and science and social studies are taught when there is “time”. I think it would work well to work on integrating reading and writing into the PLTW lessons and help teachers to make these connections. It is

> such a challenge because they feel they have to stay on these pacing guides and often are afraid to deviate from the reading/writing curriculum.

Both media specialists report that the students have a positive reception to PLTW curriculum. When MS2 was asked how the students reacted to the curriculum, she stated, “I think they loved it.” MS2 discussed a first grader that she had last year in kindergarten and the growth she has seen in him.

> I don't think so because. I don't want to say because I'm not surprised by them but I think it gives them definitely an opportunity to show their thinking in a way that doesn't always come through. For example, I had a kindergartner last year who is in first grade this year who is extremely intelligent and has such a creative little mind. He has a vision he can't make his vision happen. But through the process of last year and this year I could see his vision, I mean I could understand what he was trying to accomplish. And he's reading WAY below level he's writing way below level but there's definitely a lot of. Creativity and thinking happening and so that was really exciting but I'm not surprised by that. I think it's wonderful whenever you get kids an opportunity to show what they know in alternate ways but I don't know that it surprises me because I believe that kids often know more than what they're able to demonstrate.

Research Question Three

What are the teachers’ perceptions of student achievement following implementation of the PLTW curriculum?

The teachers felt the curriculum was a challenge to their students that have higher academic abilities. This teacher discussed her gifted students (EEE is the gifted program in the district being studied).

> I would say it was interesting to see some of my EEE friends that are you know labeled for their giftedness and creativeness and they were more so my friends that were less likely to get started because they wanted to have a direct, answer to the question. Where they were in our projects (we had to figure out how to get out of the woods and using a bunch of different. Materials) there was no right or wrong answer but the flexibility and thinking was some of my higher, that should have been my higher level thinkers was interesting. And some of my lower level thinkers were able to pick up the materials explore and play with them and figure out what they were going to do and they just made up a plan and they had some great ideas.

T2 did not refer to her gifted students, but did discuss a student that has a lot of background in science. She was surprised at how much he struggled with the PLTW curriculum, while students without as much background had an easier time.

> You know actually kind of all over. I noticed it was my, what I would consider my strongest student in science, has a lot of background knowledge, didn't get that. But some that didn't have background knowledge, got it. Yeah my guess is that well we also had issues with kids, because this was drawn out for so long, we definitely had kids that missed days. I don't think we did much, going back and reviewing and you know checking and that sort of things.

T4 had two students that surprised her when we discussed student achievement. She said, "I feel like some of them that have difficulties retaining stuff and they'll say, oh its waves. So yeah I think I've had a couple surprises. It kind of reaches kids... Yeah it reaches them in different ways." When I asked her why she thought that, she was not sure. She then went on to talk about how she would change her teaching approach for next year and had this to say about the achievement of her students.

> It might change some things this year just because I have seen a couple students that have had more difficulty retaining things and they are paying attention to things that have stuck with them so. It maybe gives more validity to that kind of crazy exploration time where it almost feels out of control but maybe something is coming out of that.

Research Question Four

What was the difference in mean scores of the first grade teachers' level of self-efficacy for those that have taught PLTW and for those that have not?

All first grade teachers in the district being studied were invited to take the survey that measured science teaching self-efficacy. The survey used one subsection to examine the teachers' self-efficacy (Friday Institute for Educational Innovation, 2012). Table 1 breaks down the results of the survey for each group of participants. The mean is the average score out of five for each group. As a group, the participants reported having a high level of self-efficacy in teaching science. Results are listed in the table below.

Table 2

Results of the T-STEM Self-Efficacy Survey

	Group		
Survey Section	All	PLTW	Non-PLTW
N	49	4	45
Mean Score	3.63	3.73	3.61
Standard deviation	.44	.20	.47

Note. All refers to all first grade teachers that responded. PLTW refers to the four teachers that implemented the curriculum. Non-PLTW are the first grade teachers that did not implement the PLTW curriculum.

Table 2 answers research question four by noting the self-efficacy for the study participants was slightly higher than the self-efficacy of those that did not implement PLTW curriculum for this study.

Chapter 4 Summary

In Chapter 4, the results of the study were reported. First grade students were given an end-of-unit assessment, and results were sent to me for comparison. All first grade teachers were surveyed to determine their self-efficacy when teaching science. Finally, the teachers and media specialists who taught the Light and Sound unit using PLTW curriculum were interviewed in order to explore their perceptions on implementation. In the next chapter, the data that was reported in Chapter 4 will be analyzed.

Chapter 5: Discussion and Conclusion

Covered in this chapter is the analysis and discussion of the study results for the examination of the implementation of the Light and Sound unit from the PLTW curriculum. Included is the interview analysis from the four teachers and two media specialists who implemented the Light and Sound unit. Also discussed are the analysis of findings from the science self-efficacy scores for all first grade teachers in the district. The T-STEM survey scores were assessed to establish the level of self-efficacy in teachers as content knowledge and comfort level in teaching science have been linked to willingness to implement new curriculum such as PLTW (Nadelson et al., 2012; Yoon et al., 2014). Analysis of the results from the PLTW student assessment data is also discussed in this chapter. This chapter provides a summary of the results in relation to the literature, the limitations of the study are identified and implications for practice, policy, and theory. Recommendations are suggested for further study and research, and the chapter concludes with a summary of the significance of the study.

Summary of the Results

The research questions were answered through the analysis of the case study interview data, student assessment scores from the PLTW Light and Sound unit assessment, and the T-STEM survey to measure self-efficacy in teaching science for all first grade teachers in the district studied. The three data methods were used to examine the implementation barriers of integrated STEM curriculum, which was delivered through the PLTW Light and Sound unit. The elementary years are the ideal time to introduce STEM concepts and curriculum (Cotabish et al., 2013; DeJarnette, 2012; Moore et al., 2014; Sadler et al., 2012; Schmidt & Fulton, 2016). During these years, foundational skills are built and interest is developed in STEM subjects and careers (Aldemir & Kermani, 2016). In contrast, interest in STEM subjects begins to decline

(Kurz et al., 2015; Yoon et al., 2014). Therefore, it is vital that integrated STEM instruction begins in the early childhood and early elementary years, and it is imperative that this implementation is effective and efficient (Aldemir & Kermani, 2016). Early exposure will establish the baseline skills through positive exploration and experiences that students can then rely on as the concepts become more difficult as they move through their school years (DeJarnette, 2012).

Five studies were located that were published after the present study began. Four of those five studies discuss creative problem solving and critical thinking as vital skills that integrated STEM education can help develop (Blackely, Rahmawati, Firtiani, Sheffield, & Koul, 2018; Cook & Bush, 2018; Dailey, Cotabish, & Jackson, 2018; Tran, 2018). Also identified in the studies was the continued need for STEM integration in the elementary years as interest in STEM peaks around 10–12 years of age (Blackely et al., 2018). Cohen (2018) studied STEM programs that were not held during the school day, typically afterschool or on weekends. He found well-trained staff were one of the necessary components to a successful afterschool program. The most recent literature continues to show the need for integrated STEM programs in the early elementary grades.

Case study methodology was utilized for the present study. The case was the implementation of PLTW curriculum in four first grade classrooms at two different elementary schools in a district in the Midwest. The case study method was chosen because the study was developed to take an in-depth look at the implementation process at these two schools. The goal was to provide modifications to theory about integrating STEM curriculum, not necessarily to generalize the results to the entire population. The study size was small and there were too many factors that were specific to the district being studied that mean the results of the study cannot be transferred to other districts.

The findings for the study implementation were mixed. Teacher and media specialist perceptions of the curriculum were both positive and negative. Participants indicated that the kits provide everything that is required and the PLTW curriculum reached students who may not have grasped the science concepts had they been taught with a more traditional method. Teachers felt, however, that the quality of the materials provided, the scheduling concerns with the media specialist, and the adjustments that had to be implemented to make the curriculum developmentally appropriate were negative aspects of the implementation. However, all four teachers did express a willingness to teach with PLTW curriculum in the future despite the mentioned concerns.

Teachers and media specialists had four common themes: materials, developmentally appropriate, school/district implementation, and student achievement. Both groups discussed the materials, mostly how difficult managing the materials was, and several discussed the quality of the materials not being very high. One teacher and one media specialist discussed the convenience of the materials coming in a kit that had everything that was needed to teach the curriculum.

Both groups also discussed the adaptations they had to make in order for the curriculum to be developmentally appropriate. For example, MS1 stated that she teaches the design process with the older students, but not as much with the younger students. She also discussed tweaking the lessons by adding videos to aid in understanding. The teachers also mentioned adding videos and making adjustments, such as lowering expectations with the writing the students did in their journals.

Only one teacher mentioned implementation across the district, and both media specialists discussed the topic. The media specialists expressed frustration with implementation as they are expected to lead the process, but the district and administration support varies widely from building to building. T4's comments were centered around the fact that PLTW is not a well-known curriculum in the district, and it often feels like a big secret that is not widely shared. She feels the curriculum would be more widely accepted if more teachers knew about it and heard more positive things about it.

The different themes had more to do with the different roles that the teachers and media specialists have in teaching and implementing the curriculum. The media specialists discussed the challenges of working with teachers and attempting to implement new curriculum. MS2 discussed the difficulties with co-teaching and involving the teachers, while trying to get buy-in from them at the start of implementation.

The important finding was in student achievement. Teachers discussed in the interviews their experience with higher-achieving students and noted the struggles those students experienced during the exploratory phase of the learning. When beginning the hands-on exploratory phase of the learning, high-achieving students just wanted the teacher to provide the right answer. The students had difficulty understanding they would be able to solve the problem presented in the lesson via the exploration processes using the hands-on materials. However, other students, including some normally lower-performing students, intuitively started exploring and manipulating the materials in different ways to solve the problems that were presented in the lesson. Teachers noted that there were students who struggled all year to retain information, yet those students were able not only to keep pace with the other students in the class, but could mindfully answer questions about the learning process. The gain in knowledge for these usually low-performing students was attributed to the hands-on exploration aspect of the curriculum. T4 made the connection when she said, “It might change some things this year just because I have seen a couple students that have had more difficulty retaining things and they are paying attention to things that have stuck with them so. It maybe gives more validity to that kind of crazy exploration time where it almost feels out of control but maybe something is coming out of that.”

Research Question 1

What are the teachers’ perceptions of PLTW’s instructional strategies and effectiveness for science instruction as opposed to instruction using the district curriculum?

Overall, the teachers expressed a mixed reaction to the PLTW curriculum. They liked the hands-on, exploration format and the fact that there was a common theme throughout the unit in the form of the continuous story. However, teachers were concerned over the length of instructional time required to present the full video introducing this story. The unit begins with a story about some children who become lost in the woods. Further ongoing student explorations via hands-on activities help the students learn about light and sound. The objective of the activities is to help the children in the story find their way out of the woods via the lessons learned regarding light and sound. Teachers felt that the students were engaged in the curriculum, however, there were some aspects that needed to be improved for further implementation to occur.

One of the areas that was discussed by the majority of the respondents was the materials provided. While there was agreement that the materials provided in the kit were helpful, the quality and management of the materials were both areas that needed improvement. First, the quality of the materials was lacking. Specifically, teachers mentioned the colored lenses that were supposed to overlap to create new colors. The lenses did not combine to make the correct color and were scratched from so many students sharing them. There were either too few materials, the materials did not work as the curriculum said they should, or they were not durable enough for three classes to share. Teachers felt that the curriculum had "powerhouse potential," however, the materials did not match this potential. This caused lots of frustration for the teachers and students.

Another area of necessary materials improvement was in the management of the materials. The teachers reported the need to share the materials and a lot of students spent their time sitting and waiting. There were also times when the students required multiple materials to conduct the hands-on component of the lessons. Teachers would be more willing to teach the units if the materials were improved. All the teachers in the study conveyed frustration with the materials, as noted during the interviews by their tone or gestures if not by their words.

Time was another theme that emerged in the coding process. Teachers did not like the length of the lesson sequence or how there were many days in-between lessons owing to the rotation schedule. Because the teachers were implementing the PLTW curriculum with the media specialist, they rotated days. For example, one of the teachers had her PLTW lesson scheduled for Monday, with Tuesday scheduled for another teacher's lesson. The third teacher's lesson was scheduled on Wednesday. Therefore, it was not until Thursday that the first teacher's second lesson in the series was held. This schedule stretched out the lessons over the course of several weeks, with lots of days occurring in between each lesson. Owing to these delays, students forgot what they had learned.

The participants felt that the PLTW curriculum needed some built-in review. Not only were the lessons given over the course of several weeks, but the lessons did not review or spiral.

Instead, the expectation was that the previous concepts were learned and the next lessons that were presented built on the previous learning. However, if a student did not understand the original concept, it was up to the teacher to come up with a way to review the concept as this was not built into the curriculum.

Other concerns had to do with the developmental appropriateness of the curriculum. While there was hands-on learning, which all six participants liked, often adjustments needed to be made to help the students understated the concepts. Teachers needed to find supplemental videos and information to teach the difficult concept of refraction. More vocabulary support was required because the concepts introduced were important. However, there was no direct teaching for the vocabulary to help students learn the words. The PLTW website was difficult and cumbersome to manipulate, with only the media specialists able to log into the site. Teachers were not offered login privileges to print out the lessons. Furthermore, a print function was not included on the PLTW website; therefore, screen images needed to be copied and pasted for printing, which was extremely time consuming. Teachers required printed copies of the lessons; both the ones used for instruction and the next lessons so they could prepare for future lessons.

As part of the PLTW curriculum, students were expected to write in their journals each day to reflect on their learning for that lesson. The teachers liked this aspect of integrating writing into the lessons, however, they had to adapt the writing task to make it appropriate for their students. For example, they had to reduce the expectation of students producing a one sentence response to the writing task. One of the teachers suggested the use of sentence starters for the journal reflection so the students could focus the content. According to teachers, the unit needed to be taught later in the school year when first graders would be ready to complete the writing tasks.

Teachers indicated that students were able to transfer the knowledge gained from the program to other situations. When students transfer their knowledge, it means they have learned the material at a deep enough level that they recognize it when they see it out of context. This was noted, for example, when students incidentally became aware of refraction from the sunlight on glasses when students were seated for a reading lesson. This new knowledge was attributed to the learning from the PLTW lessons on Light and Sound.

Teachers liked the PLTW curriculum better than the district curriculum. The lessons in the district curriculum were not connected, although the concepts were covered. In contrast, PLTW lessons built upon one another. Connections were made through the story introduced at the beginning of the course that presented the problem and set up the importance of the lessons. According to teachers, the PLTW curriculum was effective for science instruction and was viewed more favorably than previous district curriculum.

Teachers felt much more competent and comfortable teaching science lessons when they had previous training and were more knowledgeable about the concepts. Literature supports this finding that teachers feel more comfortable teaching subjects that they are knowledgeable about (Yoon et al., 2014). PLTW provides training with their units before they are taught, as well as ongoing support being available as the units are implemented (PLTW, 2014).

The final theme was school and district implementation. While PLTW is available in the district being studied, it is not widely implemented. Many teachers and administrators do not know about PLTW or that it is available. Furthermore, teachers are reluctant to try a program if they are not hearing positive comments on the program's effectiveness from their peers (Nadelson et al., 2013). There is no clear implementation plan in the district and no clear communication about the future of PLTW in the district.

Research Question 2

What are the experiences of the media specialists in working with teachers to implement PLTW? What are the media specialists' perceptions of student engagement and receptiveness to the PLTW curriculum?

The media specialists' interviews produced some of the same themes as those of the teachers, however, there were some new themes owing to the nature of their job. The themes that were the same were materials, developmentally appropriate, student achievement, and district implementation. The themes that were unique to the media specialists were training, cost, exemplar lesson, and working with teachers.

The two media specialists had different types of training in the PLTW curriculum. One of the specialists had attended a three-day training course that explored the components of the PLTW lessons. During the training, participants explored some of the lessons as if they were the students. This intensive training helped the specialist understand the principles and structure behind the construction of the PLTW lessons. For example, there are five main lessons: three that build the foundations and two that have students solve an authentic problem. The training also taught the specialist about the design process, something that is valuable when teaching the lessons to students or coaching teachers. The other specialist participated in a half day training that mostly explored the cumbersome PLTW website. This training was adequate, although teachers' responses to this limited PLTW coaching was not as positive as that for the specialist who received the intensive training. The media specialist who received more training was better able to engage teachers in the curriculum implementation. Studies back up this finding concerning teacher training benefits and indicate the critical importance of teacher support and training when implementing STEM integration (Daugherty, Carter, & Swagerty, 2014).

A theme that appeared for the media specialists and teachers was the theme of the materials. The materials were great and everything was provided in the kit to teach the PLTW curriculum. Management of the materials was difficult. Review of the lessons was needed beforehand to know how the materials were going to be used. Kits are paid for out of the media specialist's budget and to keep using them from year to year the media specialist tries to be creative with the consumable aspects in the kits. For example, a kindergarten lesson involved students building the bones in the hand using tiny bones that are provided in the kit. The students are supposed to glue the bones onto the hand when they are finished, but instead the media specialist adapted the materials so students used a Q-tip and white paint to paint on the bones to save money on consumables.

Being creative with the materials helps keep the cost down, as the program costs money not only for the kits, but to access the lessons. PLTW costs $750 per site for a license to access the lessons. Kits are quite expensive and to build up an inventory of PLTW lessons one or two PLTW lessons are purchased each year. Sharing materials is frustrating for teachers as it increases behavioral problems when students must wait for their turn.

All the kindergarten lessons are viewed as exemplar lessons by the media specialist. In particular, the human body unit was considered to be exceptional. Students look at X-rays and build the bones in the hand. The unit culminates with the creation of a cast for a broken hand. Having students create something gives students a thorough understanding of the concept being taught.

One of the unique themes for the media specialist group was working with teachers. One of the media specialists felt that she needed to carefully introduce the unit to teachers and work on getting buy-in from the teachers. The media specialist felt it was harder to get some teachers to participate in the lessons than others. To overcome this, one of the strategies she plans to use next year is to plan a meeting with the teachers to emphasize the benefits of co-teaching the unit. Actively involving the teachers in the lesson planning process might help reduce the need to force interactions with the teachers during instruction. Students that have teachers that are competent in what they are teaching have been shown to have higher achievement in math (Epstein & Miller, 2011). By working with the teacher, the media specialist can provide the teacher with the content knowledge she needs to competently teach the science in the PLTW unit.

MS1 reported that the teachers she works with are very receptive to the PLTW lessons and are willing to implement them each school year. The media specialist thinks that teachers would like to teach PLTW more often but they feel the pressures of district priorities in teaching curriculum. There is also never enough time for teachers to really develop the lessons. Planning time is a struggle, she says they often, "fly by the seat of their pants, planning in drive-by conversations at lunch or in the hallway."

The theme of developmentally appropriate appears in the media specialists' interviews as well as in the teacher interviews. One of the media specialists, for example, adapted the lessons by breaking down the design process as it is difficult for first grade students to understand. Parts of the lessons are tweaked to fit the needs of their students. For example, additional stories are read or videos are used to support the PLTW foundational information.

Time is still a challenge when implementing PLTW. Media specialists mentioned that teachers feel pressure to teach reading and writing and to follow the district pacing guides. To help ease the concern, the media specialists felt reading and writing could be further integrated into the PLTW lessons so these tested areas are covered in the lessons. Furthermore, the district needs to be clear on their expectations in implementation and needs to provide support for the teachers. Recent trends for time spent on subjects have been driven by mandated testing. With the No Child Left Behind Act came mandated testing, and the primary subjects being tested were reading and math (testing began in these subjects in 2003). Science testing does take place, but it was not implemented until 2007, and it is not used to measure adequate yearly progress (Blank, 2012). The focus on testing and making progress resulted in less time for other subjects (Lewis, 2008).

Research Question 3

What are the teachers' perceptions of student achievement following implementation of the PLTW curriculum?

All teachers reported that the students were very engaged in the curriculum. Engaging students in the curriculum is the first step for effective instruction (Moore & Smith, 2014). Teachers noted that the high-achieving and/or gifted students struggled at first with the exploration component. Students, according to teachers, were waiting to be told the answer, instead of exploring on their own.

Lower-achieving students were quick to begin the hands-on portion of the lessons. Because of the PLTW instruction, low-achieving students showed retention of the concepts by being able to answer questions about light and sound. Deep learning for the students occurred via the exploration and discovery aspect of the unit. The success of usually low-performing students has provided evidence of the validity of the program.

There was also transfer of knowledge noted. For example, in one of the classes when the teacher took off her glasses during a reading lesson, light refracted through her glasses onto a piece of paper that was on the table. The students noticed and connected it to the refraction concept learned from the PLTW lesson. If it had not been for PLTW the students, according to the teacher, would not have noticed the light refracting from her glasses. Transfer of knowledge is when students apply their learning outside of the task or problem where they first learned the concept (Dixon & Brown, 2012). This knowledge transfer requires a higher level of understanding as students must fully grasp the concept, not just memorize the vocabulary and facts associated with that skill.

Student achievement test scores showed that most of the students were able to answer the questions on the assessment provided in the PLTW curriculum. Three classrooms had an average score of 85% on their assessments. One classroom had an average score of 69%. When I discussed the results of the test with the media specialist to assess the possible reasons for the low score, the specialist mentioned that the assessment was given to the students in this class long after the unit was over. The lower scores obtained, therefore, may have been the result of waiting too long to administer the test.

Student achievement was not measured by a validated and reliable assessment. It was, however, noted by the teachers in the interviews that achievement was occurring in the classroom. The implications of the hands-on, exploratory aspect of the curriculum for students of all levels is substantial. First, lower-achieving students are finding success in learning when they have struggled with retaining concepts in other areas throughout the school year. Second, higher-achieving students are struggling with the structure of the activities, so while the content may not be difficult for them, the productive struggle they engage in is vital for their development of higher-level thinking skills.

High-achieving students often already know the answer to the problems being presented in school (Esparza, Shumow, & Schmidt, 2014). However, the answer is not always what is important. Sometimes, it is the ability to problem solve and try different solutions that is the vital learning. Through the process of exploration, higher-level students (and all students) are developing 21st century learning skills (Cook & Bush, 2018). Such 21st century learning skills include collaboration, critical thinking, creativity, and communication (Jacobson-Lundeberg, 2016). Integrated STEM education provides a method for delivering these skills by having students apply their learning to real-world problems (Khalil & Osman, 2017). Robinson, Dailey, Hughes, and Cotabish (2014) discovered that gifted students who were involved in a project-based learning unit scored significantly better than their peers that were involved in a unit that simply presented the information via textbook. While videos might be more appealing than a textbook, they are still not as engaging to students as the hands-on, exploratory learning that creates deep learning.

Research Question 4

What was the difference in mean scores in the level of self-efficacy for the first grade teachers who have taught PLTW and for those who have not?

Across the district, teachers had very similar self-efficacy scores, though the teachers that implemented PLTW had a slightly higher score. PLTW teachers had a mean score of 3.73 while teachers that did not implement the curriculum had a mean score 3.61. Most of the teachers reported that they taught the science units that the district requires. This was encouraging and shows that teachers want to teach science, and they are mostly comfortable with the subject. It is up to the district to provide a curriculum that teachers can implement and to provide training to increase the comfort level of the teachers in the content areas they teach.

A high self-efficacy score shows that teachers are more likely to use inquiry-based curriculum, such as PLTW, than teachers with a low self-efficacy score (DeJarnette, 2012). The ability of the teachers in this district is not a barrier that is impeding the implementation of inquiry-based curriculum such as PLTW. The teachers' self-efficacy scores show that they feel confident in their science teaching skills. Nadelson et al., (2013) states that teachers are more willing to modify their teaching approaches when they have seen a positive model. PLTW curriculum is not widely known in the district, and Nadelson's (2013) findings are a more likely reason than the ability of the teachers in the district being studied.

Discussion of the Results

The main objective of the present study was to gain an understanding of the perception of teachers concerning the PLTW curriculum. Although the study sample size was small, the data collected provides insights that will help with future implementation of PLTW and science curriculum in general. The themes that were identified in the analysis of the teacher interviews were: curriculum adaptations, materials, developmentally appropriate, review of concepts, student achievement, transfer of knowledge, science background of teachers, and school/district implementation. The themes that were identified in the analysis of the media specialist interviews were: training, materials, cost, exemplar lesson, working with teachers, developmentally appropriate, student achievement, and district implementation.

The extensive discussion about the materials was unexpected. Materials for the lessons can be purchased as a kit, however, the quality of the materials was below expectations. The teachers reported lots of issues with the materials, especially related to quality and management. Additionally, the cost of the kits is rather high and creative measures are often put in place so the consumables can be reused from year to year. Since the materials are not designed for this, it can result in them no longer working as intended. An example of this was the colored lenses used to explore color mixing. With 60 first grade students sharing them, they became so scratched and opaque that the colors did not mix correctly.

Both the teachers and media specialists had positive responses about the PLTW curriculum. PLTW allows students to learn concepts that they then apply to a real-life situation to solve a problem. The problem is introduced in the first lesson and then solved at the end by the students. The teachers reported that they liked this thread because it developed relevance for the students for each lesson as they learned about light and sound to solve the problem.

Student achievement was another area that was discussed during the interviews. Student achievement scores were averaged at 85% for three of the classrooms, with the fourth at 69%. Two teachers discussed how their higher-achieving students struggled with the PLTW lessons more than they do in other lessons, while some of their lower-achieving students were able to actively engage with the materials. A third teacher also noticed this and commented that two of her students that struggled to retain information in the district curriculum were retaining the information and understanding the concepts in the PLTW lessons.

During the interviews, the teachers were focused more on their frustrations with the lessons and materials than with their success in student learning. TI, T2, and T3 all implemented the PLTW curriculum for the first time in the present study, and they had lots of negative comments about the materials and the management. However, the teachers did notice transfer of learning for students, with the PLTW lessons enabling students to make connections between the subjects they were learning about and real-life occurrences.

Teaching an unfamiliar curriculum is difficult for teachers. The teachers tend to remember and focus on any frustration and are less apt to think about the achievement of students. However, teachers did recognize the validity of the “crazy exploration time” because of the resulting learning for students and the ability of students to retain information.

The self-efficacy scores for teaching science was slightly higher for those teachers who implemented PLTW curriculum than for those that did not, 3.73 vs 3.61. Teachers who took the survey also reported what science units they had implemented the previous year, with the vast majority reporting that they taught all four units of the district provided curriculum. These two pieces of information mean that the first grade teachers in the studied district are ready and willing to implement science lessons in their classroom. It is now up to the district to develop a plan and follow through with a science curriculum that can be utilized by all teachers.

There were three data points in the study: interviews, student achievement scores, and teacher self-efficacy scores. The three sets of data showed teachers that are willing to teach science, which was evidenced by the interview data and the survey data. The student achievement data showed that students are able to learn the concepts. The three sets of data supported the fact that science in important, teachers can teach science, and students can understand science.

Discussion of the Results in Relation to the Literature

Research shows that teachers are more comfortable teaching subjects they are knowledgeable about (Yoon et al., 2014). Nadelson et al. (2013) also found a link between a teacher’s level of content knowledge and their effectiveness in teaching a subject. The PLTW curriculum provides training in content knowledge and how to implement the curriculum to help teachers gain the knowledge and teaching skills required for implementing the science units. MS1 discussed how helpful she found the district training when she implemented the PLTW curriculum with her teachers. The media specialist developed an understanding of the design process through the training and was able to teach confidently. MS2 reported that she felt her half-day training was enough. However, the teachers she taught were not as receptive to the program.

Research has shown that teachers are not willing to implement something new unless they have seen the positive effects of a new program (Nadelson et al., 2013). As T4 discussed, the PLTW curriculum in the studied district is not widely known, nor is it available to all teachers. The teachers therefore do not know about the PLTW or the training process for the curriculum. Although there was initial district training in PLTW, there was no further follow-up training for the program. Administrators were not brought on board and the training that the media specialists undertook to become lead teachers in PLTW curriculum has not been duplicated. Without administrative support, and without widespread availability, there is little incentive for program implementation.

Aldemir and Kermani (2016) state that children are naturally curious and that hands-on learning through STEM helps develop a deeper understanding of STEM concepts. Developing a deep understanding of STEM topics at an early age can help students develop a solid foundation. This foundation can then lead to their sustained interest in STEM subjects as they progress through school and the courses become harder. All six of the participants reported that the curriculum was received positively by the students. One teacher stated she felt her struggling students were able to connect to the PLTW curriculum and retain the information. A positive interaction at this age can provide students with a strong foundation to build upon as they move through their schooling.

Teachers will resist implementing new curriculum or teaching methods until they are more familiar with the potential for student learning (Becker & Park, 2011). Teachers want to feel confident when teaching new lessons and new methods. Integrated STEM education requires students to discover the answer. The students must apply what they learn, which is a higher-thinking skill, and they must be able to handle not being successful in their attempts (Honey et al., 2014). They can learn as much or more from a failed attempt and a redesign as they can from a successful attempt (Moore et al., 2014).

STEM integration has enabled students to achieve at higher levels, there is deeper learning, and this integration promotes enjoyment of STEM subjects (Becker & Park, 2011; Moore & Smith, 2014). The frustrations the teachers feel with the management and quality of materials needs to be discussed as well as the long-term benefits of the new curriculum approach so that the teachers understand how the implementation benefits students. That is why teacher training of program implementation and support for teachers while implementing the approach is critical. In addition, administrative support is crucial. The benefits of integrated STEM education are not always immediately evident. However, this type of exploratory, hands-on learning has a lasting long-term effect and develops deep learning for students.

In four of the five studies that were published after this study began, 21st century learning skills are mentioned. Although these are not skills that are explicitly taught in PLTW curriculum, they are skills that are developed through the exploratory process. The 21st century learning skills are those skills that make students employable in the future, including adaptability, communication skills, and problem-solving skills (Hilton, 2010). Students who learn through an integrated approach have higher achievement than those who do not (Becker & Park, 2011). Integrating the subjects and having students solve a problem based on a real-life problem requires them to apply what they have learned, not just memorize it (Honey et al., 2014).

Limitations

Interviews were the main source of data collection, which makes the findings based primarily on teacher perception and the accuracy of their responses. Student achievement was examined using descriptive statistics to look for trends and not significance through statistical analysis. The study was not set up to closely examine student achievement, only teacher perceptions. An assessment to measure overall student achievement in STEM subjects in early elementary was not available at the time of this study.

Implication of the Results

All six participants (four teachers and two media specialists) reported that the students were receptive to PTLW curriculum. Hands-on exploration, coupled with the design process, allows students to discover the solution to a real-life problem. The students were actively engaged and their ability to retain the information surprised their teachers. The interviews indicate the teachers like the curriculum, but would have to adapt it in order to use it again. The need for adaptations causes frustration for the teachers, and can negatively affect the teachers' willingness to implement the curriculum. However, by requiring training before implementation, the teachers can learn about integrated STEM and the benefits to student learning. They will be able to look past the frustrations because they will understand the end results.

PLTW curriculum is not compulsory, nor does every school have access to it. This combination makes budgeting difficult when determining who pays the school fee and who pays for the kits. According to teachers, the PLTW curriculum is a big secret. Only the media specialists had a login to the website and, if a teacher wanted to view the lessons beforehand, the medial specialist had to login to the computer for the teacher. Therefore, teacher access to the

PLTW website is required and vital for assisting teachers in planning PLTW lessons and units, as well as giving them access to support in the way of training videos.

Media specialists discussed the cost of the program and how the expense for the kits is taken out of the media specialist's budget. Purchasing the kits results in less money available to spend on books for the library. The cost of the program is $750 per school for a license to access the curriculum. The kits cost extra and include consumables that need to be replaced each year. The media specialist tries to find creative ways to reuse the consumables so she does not have to purchase new ones out of her budget each year but reusing materials that are meant to be consumable results in frustrations such as the ones experienced with the colored lenses. Due to many students using them, they were scratched and did not produce the results the curriculum stated they should when they were combined to make new colors. Funding is not an area the researcher has any knowledge about, but I do know that the district has purchased a curriculum that costs $500 per elementary school building for next school year (M. Szydlowski, personal communication, February 22, 2018). The higher cost of PLTW curriculum, plus the need to purchase the kits, is an obstacle for further PLTW implementation in the district.

Implications for Practice, Policy, and Theory

Practice

One of the biggest revelations for me was the fact that PLTW was not as positively received as I expected it would be. Having gone through the same three-day training course as the media specialist had, I knew how powerful the curriculum could be. After conducting the research for this dissertation, I also knew that integrated STEM education is a very effective method of delivering instruction (Becker & Park, 2011; Moore & Smith, 2014). While the teachers' overall perception was positive, there were negative reactions to the curriculum, which was unexpected. In my opinion, this is because there was little to no training conducted for the teachers before the PLTW curriculum was implemented.

Future implementation should make the three-day training compulsory for media specialists. Teachers need support and guidance as they integrate STEM curriculum (in the form of PLTW for this study) and the media specialists are already serving in the role of support to teachers with technology lessons. In order to provide the proper support, the media specialists must receive the proper amount of training (Daugherty, Carter, & Swagerty, 2014). In this study, the media specialist that had more training had a teacher that had a more positive view on the program as she was receiving the proper support.

Teachers also need to participate in the full-day training that qualifies them to then be a PLTW teacher and have access to the curriculum. The training provides in-depth understanding of how the curriculum works across the grade levels and the research behind the approach. This understanding can be passed along to teachers who are coached in PLTW, which would help provide the buy-in to the program from teachers. Teachers need training in order to fully realize the benefits of integrated STEM education (Becker & Park, 2011).

The other revelation is that teachers want to teach science and they understand how much students love it. There is so much instruction that a teacher is expected to deliver each year that there is literally not enough time to implement it all. Integrating STEM subjects can be achieved not only with science, technology, engineering, and math but also with reading and writing and even social studies. Teachers are not always aware of the benefits of integrating STEM subjects (Becker & Park, 2011). There is a lack of guidance provided to teachers on the most effective way to integrate STEM and there is no single way that is best for implementation (Guzey et al., 2016). Providing teachers with training and guidance on integration might be the best way to teach them how to integrate and make the most of their instruction time. This training allows teachers to understand that they are building a foundation that students will use for the rest of their school and work career.

Policy

The results of the present study show the need for a district-wide policy on PLTW curriculum. If this curriculum is the district science curriculum, then it should be purchased for all the schools to use and there should be kits provided by the district available for check out. It should also be required that the teachers go to the training provided by PLTW. Training increases a teacher's comfort level in teaching a unit or program (Yoon et al., 2014). When a teacher feels more comfortable, the teacher is also more effective (Nadelson et al., 2012). Training is the only way to ensure teachers realize the benefits integrated STEM education provides over other types of instruction. Finally, all media specialists that are acting as lead teachers and co-teaching with the teachers should be teacher trained in PLTW. The district needs to provide this curriculum to all teachers and media specialists if this is the curriculum that will be used.

Promoting the PLTW curriculum in the studied district has fallen to the media specialists. Media specialists are not administrators, and therefore teachers do not see them as having the authority to implement new curriculum. Some teachers are willing to try new methods, but some are very resistant. Administrators, however, often do not know what PLTW is, nor that it is available for implementation. There should be an information session for administrators so they can learn about the PLTW curriculum option and decide whether they are interested in the implementation of the program. At the least, administrators can communicate to teachers about the curriculum benefits and what the expectations are for implementation. Administrative support is also necessary for budgeting money for materials needed for implementation (Dailey et al., 2018).

Theory

Research shows that STEM subjects have higher student achievement when they are integrated (Becker & Park, 2011; Honey et al., 2014) and that STEM subjects need to be introduced at an early age (Aldemir & Kermani, 2016; DeJarnette, 2012; Kermani & Aldemir, 2015). PLTW is a research-based, integrated STEM curriculum that can meet the needs of elementary integration. The present study showed that students are interested in science and their enthusiasm for learning increases dramatically when they are provided opportunities to naturally explore using hands-on activities. From the student's view, PLTW was fun and engaging, and was a positive experience. While the teachers indicated that there were some areas of improvement needed, they all agreed that PLTW was a valuable resource and worth implementing.

The experience the teachers reported on student achievement is notable. PLTW curriculum has the potential to reach all students, at both the low and high end of the learning spectrum, with very little differentiation required. The hands-on, exploratory design automatically challenges students. The lower-achieving students will try and try until they reach a solution, which is a powerful learning method as often students will learn from the process of redesigning their ideas through experimentation (Moore et al., 2014). Higher-achieving students learn how to think and problem solve and learn that there is not always only one right answer.

Recommendations for Further Research

At the time of this study, a valid and reliable assessment for early elementary students in STEM was not available. To assess the quality of integrated STEM curriculum, a developmentally appropriate assessment needs to be created and validated. This type of assessment will provide researchers with a common method for evaluating student achievement gains in integrated STEM curriculum. There also needs to be a full program evaluation and an analysis on the effects of PLTW on student outcomes.

Research on integrated STEM curriculum at the elementary level is not nearly as prevalent as it is for secondary education, and even less so for the early elementary years. Research that focuses on integrating STEM in early childhood and early elementary school can have a significant impact as it is in this age group that STEM interest needs to be cultivated. A longitudinal study would be a powerful next step; one that explores the level of interest of a group that received early and regular integrated STEM curriculum compared to a group that did not. Unfortunately, this would take a number of years, during which time we will continue to lose students in the leaky STEM pipeline.

There have been few studies on the affect hands-on learning has on lower-achieving students. Prokop and Fancovicova (2017) conducted a study that showed hands-on activities have a positive influence on children's attitudes toward science. Dieser and Bogner's (2016) study shows that hands-on approaches have a positive influence on cognitive achievement. However, neither of these studies examined specifically the impact hands-on learning can have on low-achieving students. Conducting a study that examines the link between low-achieving students and hands-on learning would be another recommendation for further study.

Conclusion

Integrated STEM curriculum is important to the future of the United States. Students' interest in STEM subjects needs to be developed at an early age for them to continue to pursue STEM subjects as they move through secondary school and into college. If students do not develop their interest early in STEM subjects, they tend to lose interest in those subjects as career choices. Integrated STEM curriculum implemented during the early elementary years can develop that interest as shown by the normally lower-achieving students who attainted substantive growth through the hands-on aspects of the PLTW curriculum

Although PLTW curriculum is research based and high-quality, the quality of the resources provided with the curriculum is lacking. Another concern is cost. PLTW curriculum not only requires a yearly school license, but also the kits must be purchased to effectively deliver instruction. The use of the PLTW curriculum in the studied district is not widespread due in part to the cost. Not all schools are able to invest the funds needed to provide this curriculum as an option for teachers.

Another area that needs improvement is the delivery of the curriculum. The PLTW website was described as cumbersome and difficult to navigate. Teachers are not granted access to the PLTW website due to PLTW curriculum access controls, which makes it difficult for teachers who require the lesson material in advance. Another example is the lack of a print feature on the PLTW website causing teachers to look for creative ways to print copies of the lessons in advance. Printed copies of lesson are easier for teachers to use when instructing the students. Another problem is if the website is down, then the teacher will not have access to the lessons for that day.

The research questions for this study explored the perceptions of teachers and media specialists who implemented the Light and Sound unit from the PLTW curriculum. While there were positive aspects of the program, there were many concerns as well. Based on the results from the interviews, and the availability of the Mystery Science curriculum, I do not know that

PLTW will be extensively used in the studied district. I also do not think that PLTW has enough support from the administration for wider implementation to occur.

Although there are issues with implementation such as materials and scheduling, the benefits to learning from the PLTW curriculum are substantial. The most important finding from this study was the fact that integrated STEM curriculum, such as PLTW, has the innate ability to reach and challenge students at whatever level they are at in their learning. Using the hands-on approach, students can experiment and find solutions. Students, through the process, develop an understanding of the concept and can apply their learning. Integrated STEM curriculum teaches students how to solve problems, communicate, work on a team, and develop innovative thinking (Bybee, 2010).

Training, however, is vital. Instead of continuing to purchase new curriculum, the district should offer more training. This would increase teacher content knowledge and access to collaboration opportunities with other teachers and content experts to help determine the best practice for instruction in STEM. With the proper support, teachers will develop confidence in their teaching and grow and learn to provide the most efficient and effective instruction to their students. Proper training in integrated STEM would help alleviate the frustrations felt when implementing curriculum for the first time and allow teachers to see the amazing growth opportunities PLTW curriculum can offer students.

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Appendix A: Teacher Interview Protocol

Teacher Interview Protocol

Good morning (afternoon). My name is Kaley Keith. Thank you for taking the time to discuss STEM instruction and Project Lead The Way with me. The purpose is to discover the strengths and weaknesses of Project Lead The Way curriculum and to share your experience with implementation. There are no right or wrong answers but the objective is to get your perceptions on the program and STEM curriculum. I would like you to be feel comfortable about saying what you actually feel and think.

Tape Recorder Instructions

If it is OK I will begin taping the conversation. The purpose is so that I do not lose any information on important points that you are making. All comments will remain confidential. Only codes and not real names will be used. I will delete the tape once transcribed and member checking is done. I will confirm the information with you after transcribing to make sure it is correct and what you actually wanted to convey.

I have a few questions I would like to ask:

Q. 1. First please tell me about your background as a teacher.

Q. 2. Tell me a little about your schooling and where you are from?

Q. 3. Tell me about your science background? Do you remember your college classes? Have you had any science-specific PD?

Q. 4 Did you teach first grade last year? What science units do you normally teach?

Q. 5. Have you ever had Project Lead The Way training?

Q. 6. Have you ever taught Project Lead The Way? With a mentor, such as media specialist or a coach?

Q. 7. If so, what did you think of the training? What did you learn from the training? How was it different from other trainings, science or otherwise?

Q. 8. Did you use the training when you taught the unit?

Q. 9 Which strategies did you find most effective in Project Lead The Way curriculum? How did you utilize those strategies during instruction?

Q. 10. Describe a lesson from the unit that you found exemplary. Why did you pick that lesson?

Q. 11. How did you engage learners in the curriculum?

Q. 12. How did the students react to the instruction? Any surprises? Behaviors?

Q. 13. What about achievement? Did you notice any excelling at the projects? Any that didn't? Any surprises?

Q. 14. What changes would you make for the next time you teach Project Lead The Way?

Q. 15. How has this experience changed the way you teach? Or has it?

Q. 16. What was the most challenging aspect of implementation as a teacher?

Q. 17. How did your experience in teaching Project Lead The Way different from the district curriculum?

Q. 18. What suggestions do you have for future training in Project Lead The Way curriculum?

Q. 19. Any other comments, suggestions, thoughts, about Project Lead The Way curriculum, or science instruction?

Thank you so much for your time. I will send you a document to review for accuracy. Is it OK if I contact you if I have any follow up questions?

Appendix B: Media Specialist Interview Protocol

Good morning (afternoon). My name is Kaley Keith. Thank you for taking the time to discuss STEM instruction and Project Lead The Way with me. The purpose is to discover the strengths and weaknesses of Project Lead The Way curriculum and to share your experience with implementation. There are no right or wrong answers but the objective is to get your perceptions on the program and STEM curriculum. I would like you to be feel comfortable about saying what you actually feel and think.

Tape Recorder Instructions

If it is OK I will begin taping the conversation. The purpose is so that I do not lose any information on important points that you are making. All comments will remain confidential. Only codes and not real names will be used. I will delete the tape once transcribed and member checking is done. I will confirm the information with you after transcribing to make sure it is correct and what you actually wanted to convey.

I have a few questions I would like to ask:

Q. 1. First please tell me about your background as a media specialist.

Q. 2. Tell me a little about your schooling and where you are from.

Q. 3. Tell me about your science background. Do you remember your college classes? Have you had any science-specific PD?

Q. 4 Did you implement PLTW in your building last year at any grade level? What units did you implement? Do you have ones that you have taught over and over?

Q. 5. What was your experience with the training from PLTW? What did you learn from it, how was it different from other trainings you have had?

Q. 6. Did you use the training when you taught the unit?

Q. 7. Which strategies did you find most effective in Project Lead The Way curriculum? How did you utilize those strategies during instruction?

Q. 8. Describe a lesson from the unit that you found exemplary. Why did you pick that lesson?

Q. 9. How did you engage learners in the curriculum?

Q. 10. How do your teachers react when you implement PTLW curriculum together?

Q. 11. How did the students react to the instruction? Any surprises? Behaviors?

Q. 12. What about achievement? Did you notice anyone excelling at the projects? Any that didn't? Any surprises?

Q. 13. What changes would you make for the next time you teach Project Lead The Way?

Q. 14. Do you have a plan for recruiting more teachers to implement PTLW curriculum?

Q. 15. What was the most challenging aspect of implementation as a media specialist?

Q. 16. What suggestions do you have for future training in Project Lead The Way curriculum?

Q. 17. Any other comments, suggestions, thoughts, about Project Lead The Way curriculum, or science instruction?

Thank you so much for your time. I will send you a document to review for accuracy. Is it OK if I contact you if I have any follow up questions?

Appendix C: Form for Entering Student Assessment Data

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Teacher Name

Please enter student scores below.

Student 1

0

1

2

3

4

5

6

7

8

Appendix D: Demographic Table

Table 1

Racial Breakdown of District – Percentage of Population

	White	Black	Hispanic	American Indian/ Alaska Native	Native Hawaiian or Other Pacific Islander	Asian	Multi	Total Minority
District Totals	60.3	20.0	6.5	0.4	0.8	5.1	7.3	39.7
Bldg 1	42.1	36.2	4.9	0.9	0.4	0.7	14.8	57.9
Bldg 2	45.8	34.4	6.1	0.5	0.5	1.7	11.1	54.2
Bldg 3	33.8	45.8	4.9	0.3	0.3	0.3	14.6	66.2
Bldg 4	75.0	8.8	3.4	0.5	0.2	4.9	7.3	25.0
Bldg 5	28.2	34.6	24.0	0.5	0.5	4.0	8.2	71.8
Bldg 6	59.5	24.4	5.4	1.5	0.0	2.0	7.3	40.5
Bldg 7	36.8	35.5	8.3	0.2	0.7	8.6	9.9	63.2
Bldg 8	68.2	12.6	3.4	0.0	0.0	11.0	4.8	31.8
Bldg 9	63.4	13.7	4.2	0.0	0.0	13.1	5.6	36.6
Bldg 10	56.1	17.6	5.7	0.0	0.3	12.2	8.2	43.9
Bldg 11	85.1	3.2	4.5	0.0	0.0	0.9	6.3	14.9
Bldg 12	78.7	6.6	2.9	0.0	8.5	3.2	0.0	21.3
Bldg 13	56.1	11.1	21.7	0.8	0.0	3.6	6.7	43.9
Bldg 14	56.5	21.7	6.5	0.5	0.5	2.6	11.7	43.5
Bldg 15	56.7	15.2	6.2	0.0	0.0	13.1	8.8	43.3
Bldg 16	73.8	7.9	2.5	0.4	0.0	5.4	10.0	26.3
Bldg 17	67.9	13.0	5.3	0.4	0.2	5.3	8.0	32.1
*Bldg 18	74.3	6.7	6.7	0.5	0.2	3.4	8.2	25.7
Bldg 19	60.8	20.6	4.5	0.5	0.0	3.3	10.3	39.2
*Bldg 20	84.2	3.5	2.3	0.6	0.0	1.2	8.2	15.8
Bldg 21	33.2	40.7	9.5	0.3	0.0	3.6	12.8	66.8

*PLTW curriculum was implemented at these buildings

Appendix E: Statement of Original Work

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

Statement of academic integrity.

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

Explanations:

What does "fraudulent" mean?

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

What is "unauthorized" assistance?

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

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

Statement of Original Work

I attest that:

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

Digital Signature

Kaley Keith

Name (Typed)

June 5, 2018

Date