TEACHER PERCEPTIONS OF STEM TEACHING METHODS AND IMPLEMENTATION IN THE SECONDARY CLASSROOM

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Abstract

The purpose of this qualitative research study was to examine secondary teachers' perceptions of integrated STEM education. The data collected and analyzed from this study help promote a greater awareness of teachers' perceptions of implementing a STEM curriculum in their classrooms. The qualitative study contained data collected from online questionnaires, semi-structured interviews, and classroom observations of traditional teachers. The findings acknowledge that traditional teachers incorporate STEM teaching methods to some degree but need additional professional development to successfully integrate STEM education. The study identified that traditional teachers perceive STEM education as time consuming and that they lack the confidence to implement STEM projects.

Keywords: STEM, professional development, project-based learning, critical thinking skills

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Dedication

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Chapter 1: PURPOSE AND ORGANIZATION

Background of the Study

The field of education is a continuously changing discipline that leads teachers on a quest for the discovery of new, more effective teaching methods. With a worldwide growing interest in the fields of science, technology, engineering, and mathematics (STEM), teachers begin to ask questions such as "What does it mean to teach STEM?" or "How do I teach STEM?" A common misconception leads teachers to believe that these teaching methods should only be used within these four STEM disciplines, but STEM methods can be applied across all curricula. The interdisciplinary approach to teaching a STEM curriculum often makes it difficult to implement. As a result, frustrated and discouraged teachers abandon the thought. The goal of STEM teaching is to help students discern connections across disciplines through long-term engagement in tasks that require extensive problem solving and application (Lesseig, Slavit & Nelson, 2017). In the field of education, the way something is learned is as important as the content being taught. However, aligning these projects with an already crowded curriculum is a daunting task for some teachers. The benefits of a STEM curriculum have been proven to outweigh the difficulty of implementation. By engaging students in STEM-based curricula, student interest and attitude regarding STEM subjects is improved. Student attitude influences the students' motivation to study STEM subjects and seek employment in a STEM-based career (Maltese & Tai, 2011). Despite these findings, some teachers are not willing to change previous methods and incorporate STEM methods. Also, many do not realize that numerous methods already implemented are essentially STEM methods. Findings show that the teachers' perception of STEM, their individual knowledge, and how well they understand the knowledge is inherently connected to the efficiency of STEM delivery in their own classroom practice (Bell, 2016).

Statement of the Problem

Teachers, particularly those who teach non-STEM disciplines and those who teach in rural districts, have a negative perception of the implementation of STEM teaching methods and progressing toward an accredited STEM curriculum (Goodpaster et al., 2012). The lack of confidence due to the lack of training has a direct effect on the teachers' perception of the curriculum. Also, due to the lack of education, many teachers do not realize that they already incorporate STEM teaching methods into their lessons. One component of the American identity is built upon the idea of technology and engineering. As these disciplines become a part of everyday life, it is imperative that students develop the critical thinking skills necessary for academic and professional success. The first Nation's Report Card in Technology and Engineering Literacy (TEL) indicated that fewer than half of America's 8th graders are on course to become proficient in the skills necessary to succeed in the workplace, with economically disadvantaged and minority students falling the furthest behind ("Left to Chance: U.S. Middle Schoolers Lack In-Depth Experience with Technology and Engineering," 2016). Many students receive very little exposure to technology outside of school, especially those in low-income households or rural areas where digital access is not available. This great decline in skilled workers, or "skills gap," has created a need for incentives for teachers to provide STEM instruction. During the State of the Union Address of 2013, President Obama addressed the need for higher quality instruction. He encouraged schools with incentives and stated, "We'll reward schools that develop new partnerships with colleges and employers, and create classes that focus on science, technology, engineering, and math—the skills today's employers are looking for to fill the jobs that are there right now and will be there in the future," (Obama, 2013). With increased national and state funding available for building K12 STEM capacity, a common solution has been the establishment of separate, accredited STEM institutions and the integration of STEM programs (e.g., Project Lead the Way, 2014) within larger school districts.

Purpose of the Study

The purpose of the study was to determine teacher perceptions of implementing STEM teaching methods in the classroom and to discover what methods were already being used. The teachers participating in the study were employed at a large comprehensive high school in rural East Tennessee where traditional teaching methods are practiced. The study provided information about how teachers feel regarding learning about STEM curriculum and applying those methods in their classrooms. To meet future demands, the research school must be prepared to offer the rigorous curriculum necessary should the opportunity for accreditation arise.

Significance of the Study

This study was chosen because of the need for a more rigorous curriculum to meet the demands of industry and higher education. There are numerous demographic discrepancies among student participants such as ethnicity, socioeconomic status, family education levels, and post-secondary plans. The results of the study would offer information regarding the amount of training and professional development needed to provide teachers with the skills to implement a STEM-driven curriculum. This information is useful for determining the best teaching methods for college and industry bound students. The conclusion of the study provides the research school with information concerning the amount of support necessary to equip teachers with the resources they need to effectively practice STEM teaching methods.

Theoretical Framework

The goal of any teacher should be to provide the highest quality of instruction possible. Studies have revealed that students are more likely to be engaged in a lesson when STEM methods are used. The increased engagement fosters the growth of critical thinking skills and encourages interest in the pursuit of a STEM major. In the classroom, the constructivist perspective of learning can suggest numerous teaching practices. Students are encouraged to practice active learning strategies such as experiments and real-world problem-solving to form and reflect on information. Students become capable of recognizing the development of knowledge and how their understanding is changing. The teacher's responsibility is to be aware of students' preexisting conceptions and guide the activity to address them and then build on them (Mayer, 2009).

Research Questions

The study was designed to determine teacher perception of STEM teaching and what methods are currently being practiced. The following research questions are the focus of the study:

1. By what methods do teachers in a traditional high school setting incorporate STEM teaching methods into their instruction?
2. What are the perceptions of traditional teachers regarding the STEM curriculum?
3. What additional professional development do teachers need to feel comfortable about incorporating STEM lessons into their curriculum?

Rationale for the Study

The development of students' critical thinking skills is a topic of concern. According to ACT, the United States is a STEM-deficient nation (ACT Inc., 2017). It is a fact that workers in STEM fields are in high demand. The demand will increase 8.9 percent by the year 2024.

Education policymakers are emphasizing the importance of developing STEM programs to accommodate this need for skilled workers. According to ACT, not enough students are equipped for these STEM opportunities. Research shows that teachers are critically important influences who impact student outcomes later in life. Any educator strives to provide students with the skills required to experience success after graduation. However, the teachers' perceptions of STEM and the ability to implement the methods needs improvement. This research sought to determine the effect of STEM teaching methods on the engagement of the students and provide the information to educators and administrators. The data collected can be used to determine the best teaching strategies and allow for proper professional development to improve the academic achievement of students.

Researcher Positionality Statement

The researcher, who has a Bachelor of Science in Nutrition, a Master of Arts in Teaching, and an Educational Specialist degree in Educational Leadership. She has 4 years of science classroom experience at the high school level. The work experience has afforded the opportunity to observe numerous forms of science instruction. The researcher's role in the study included evaluation and comparison of specific traditional and STEM teaching methods. Some of the methods studied have been personally utilized in the researcher's experience as an educator.

Limitations and Delimitations

Numerous factors that could have impacted the outcome of this study were considered when designing the proposal for this study. One categorical limitation of this study is the sample of students. The school is a large, comprehensive high school with students from many backgrounds and socioeconomic statuses. The school is set in a rural area and differs greatly when compared to an urban school. The resources available to rural schools are limited and can minimize the ability to provide technology that is readily available to other school districts. Teacher quality and effectiveness is also a limitation of this study. The teachers are evaluated using the same rubric, but teacher quality varies. This can influence engagement of the students irrespective of the teaching method being used. A delimitation of this study is that the study only uses high school teachers conveniently selected from one high school in rural East Tennessee. Ethnical diversity is restricted because the student population is 90% Caucasian.

Definition of Terms

Critical Thinking is a multilayered concept that requires people to think theoretically, to contextualize material into a tailored context, and parallels a constructivist stance (Vejar, 2013).

Flipped Learning is an educational tactic in which direct instruction moves from classroom to the individual learning space. Students are first exposed to new material on their own time by completing an independent activity such as watching a video lesson. As a result, the classroom is changed into a self-motivated, collaborative learning setting where the instructor directs students as they apply perceptions and participate imaginatively in the content material (Bauer-Ramazani, et al., 2016).

Project-based Learning is an instructional strategy that has been proven to be effective because it permits students to be in control of their own learning development. By contributing to a project-based learning model, students can build their personal knowledge and reflect on their learning projects, resulting in improved drive and increased confidence (Myeong-Hee, 2018).

STEM Education is an interdisciplinary method of education where cognitively demanding academic ideas are joined with real-world examples as students apply science, technology, engineering, and mathematics in situations that develop connections between schools, communities, occupations, and the international enterprise. This promotes the growth of STEM literacy and with it the capability of competing in the new economy (Tsupros, Kohler, and Hallinen, 2009).

Student engagement is the level of attention, inquisitiveness, concentration, confidence, and desire that students display when they are learning or being educated, which encompasses the students' degree of enthusiasm to acquire knowledge and advance in their educational careers (Lekwa, Reddy & Shernoff, 2018).

Organization of the Document

This dissertation was developed using the guidelines provided by Carson-Newman University and the American Psychological Association. This research study was organized into five chapters. The first chapter contains background information and identifies the problem and the purpose of the study. Following these areas is a discussion of theoretical framework. Research questions are identified, and limitations and delimitations are stated. Key terms of the study are defined to assist the reader with new terminology. Chapter two provides a review of literature related to the study. This includes previous studies and findings associated with the dissertation topic. Chapter three offers details on the methodology used during research. The fourth chapter reviews the results of the study including the effect of teaching methods on student engagement. Chapter five highlights conclusions drawn from the study and includes recommendations based on the conclusions of the research. The final section of the paper is the appendix which contains references relative to the research of this study.

CHAPTER 2: REVIEW OF LITERATURE

Problem-solving skills are essential to success in everyday life, not just during a student's academic years. Improving students' critical thinking skills is widely referred to as the essential outcome of education (Heft & Scharff, 2017). Due to the rapid advances of technology, the development of these skills is imperative. STEM teaching methods can be used to successfully prepare students for the challenges they will face after graduation. Multiple studies have concluded that academic institutions are not very effective in developing students' critical thinking skills (Arum & Roksa, 2011). This skills gap is not the result of the lack of motivation of educators or students. Instead, it can be attributed to the lack of information and training opportunities available to successfully integrate STEM teaching methods. STEM education is presented as an instructive technique generating interdisciplinary connections among science, technology, engineering and mathematics, and application-oriented approaches (Sarı, Alıcı & Şen, 2018). Generally, STEM education refers to the incorporation of the STEM disciplines into content, allowing students to solve problems encountered in everyday life. This permits students to be innovative, creative, logical thinkers while using critical thinking skills to solve real-world issues. Students can make connections between disciplines and develop a design process to successfully complete a task. Problem-solving skills, ingenuity, and design are defined as the rudimentary skills of STEM education (Baine, 2009). Problem-based learning is becoming popular in K-12 and higher education to create an atmosphere that fosters the growth of skills such as communication, teamwork, high-level thinking, and problem solving.

Historical Background

The STEM acronym was presented in 2001 by administrators of science at the US National Science Foundation. In the early 2000s, the integration of the STEM disciplines in the

United States rapidly increased as the result of the publication of numerous significant reports. The 2005 report *Rising Above the Gathering Storm,* of the US National Academies of Science, Engineering, and Medicine, highlighted the connections between affluence, knowledge-intensive jobs reliant on on science and technology, and the continual need to address the problems of society. Students in the United States were not achieving success in the STEM disciplines when compared to students of other countries. The report predicted consequences if the United States could not compete economically due to a poorly equipped work force. As a result, more focus was placed on science, math, technology exploration, economic policy, and education. These areas were thought to be the critical point of improving American prosperity (Olsen, Arrison, & Committee of Science, Engineering, and Medicine, 2005). Other international studies such as TIMSS (Trends in International Math and Science Study) which compares mathematics and science knowledge of 4^{th} and 8^{th} graders, and PISA (Program for International Student Assessment), a triennial assessment of the skills and knowledge of 15-year old students, raised concerns about the underperformance of students in the United States. When compared to international students, the United States ranked 21^{st} out of 30 countries assessed for performance of scientific ability and knowledge. The results prompted the development of a bipartisan congressional STEM Education Caucus. Members of this Caucus noted, “Our knowledge-based economy is driven by constant innovation. The foundation of innovation lies in a dynamic, motivated and well-educated workforce equipped with STEM skills (Hallinen, 2017).” Following the STEM initiative, studies were conducted to determine the needs of institutions and appropriately develop the solutions necessary to improve the delivery of STEM disciplines. Administered by Carnegie Mellon University and the Intermediate Unit 1 for STEM education, the study concluded that US educators were uncertain of the implications of STEM and lacked the knowledge to guide students into those fields (Tsupros, Kohler, & Hallinen, 2009). These findings encouraged US state governors to seek methods to increase essential STEM knowledge and competencies of high school graduates. Six states received grants from the National Governor's Association to align K-12 state standards and assessments to postsecondary and workforce expectations and to examine and improve the teaching capacity and increase the STEM teaching force. This included the establishment of specialized schools, development of an effective curriculum, and standards for improved Career and Technical Education (CTE) that would prepare students for STEM-related careers.

Disciplines of STEM

Science, which is associated with the need to understand, is the foundation of technology. Science seeks to answer the questions about what subsists in the world and the processes by which they operate. All academic institutions offer courses that help to provide understanding of the natural world. Courses included in the science discipline include biology, chemistry, astronomy, geology, etc. Scientific processes include exploring, inquiring, discovering, and using the scientific method. (Dugger, 2010).

Technology instruction is one of the focus areas encompassed in the drive for STEM restructuring. Some believe that technology instruction can encourage the development of science, mathematics, and engineering concepts and principles for creating resolutions to real-world issues, whether that is bridge construction or creating frameworks to support medical research. Technology education is taught by design and production skills that oftentimes result in the building of constructed pieces (Ritz & Fann, 2015). Since the year 2000, drastic changes have been noticed in the field of education and the shift to technology-driven teaching, which is transitioning from learning supplemented by technology to student-driven classrooms where the learning is fueled by technology (Dolenc, Aberšek, 2015). While this may provide new opportunities, this type of teaching requires a different approach of educators, a different way of thinking toward students and toward learning in general, creating a completely different type of school climate (Fiksl et al., (2017). According to a 2012 research study conducted by Pew Research Center, 78% of teens possessed a cell phone, 38% a smartphone, and 80% a desktop or a laptop computer (Wordmald, 2015). These numbers have continued to rise steadily since 2007. With the students' constant connection to technology at home, it is understandable to desire the same connection at school. However, it is dependent upon the teacher what type of technology is implemented during class time. Furthermore, some district policies prohibit the use of smart phones during school hours, thus pushing teachers to find other methods of engaging students. The current age span of teachers spreads from those who have been exposed to technology in their daily lives to those who have taught for 20 years without computers. This results in substantial differences among teachers' comfort levels of integrating technology in the classroom (Hoffmann & Ramirez, 2018). The reluctance of teachers to use technology can often be attributed to lack of confidence due to unfamiliarity and the fear of wasting time. Also, teachers fear looking incompetent in front of students and risking losing control of the lesson. One study shows an improvement in the confidence of teachers by exposing preservice teachers to the implementation of technology during a science methods course (Rehmat & Bailey, 2014). Student motivation is why technology integration is supported in schools. Student-centered technologies not only increase the motivation of students and their academic performance, but interactive technologies enable the teacher to provide differentiated instruction and motivate the students who usually struggle.

According to Dugger (2010), engineering is the profession in which a knowledge of the mathematical and natural sciences that is gained by training, expertise, and practice is exercised to develop ways to apply economically the resources and forces of nature for the benefit of civilization. The core subjects of K-12 education tend to remain static over time with the basics of science, English language arts, and math remaining the same. The content rarely changes other than being built upon to expand old theories when affected by new discoveries. Thus, these subjects have remained relevant and are the focus of K-12 education. There are some subjects with a more fluid content that allow for more adaptations depending on the situation. Modern Technology and Engineering Education (TEE) changes with advances in technologies and global economies and practices (Strimel et al., 2016). This can be observed through the multiple name changes this type of education has endured over time. In the late 1800s, Manual Training was included as a subject but did not endure as economic changes and new education models arose. By the turn of the century, Manual Training evolved into Manual Arts, and subsequently into Industrial Arts. Each transition is indicative of a changing economy and technological advances which render the prior methods obsolete. This is repeated throughout the history of the profession, with the most recent changes of Industrial Arts Education to Technology Education and finally to Technology and Engineering Education in the context of STEM education.

Mathematics is the science of patterns and associations and provides a specific language for science, technology, and engineering (Dugger, 2010). Data collection for research studies, calculations used by engineers and architects, and the development of new technology requires the knowledge of mathematics. When new developments in mathematics arise, this tends to stimulate new developments in technology. A student’s self confidence in math is a good predictor of the pursuit of STEM careers. It was found that self-efficacy beliefs are an important factor influencing a student’s attitude, achievement, and educational and career choices. Feelings of self-efficacy can overcome other variables, such as anxiety, mathematics experiences, perceptions of mathematics and self-regulation views (Nicolaidue & Phillipou, 2003).

Importance of STEM Education

The variances between STEM education restructuring, and other educational reform efforts, can be attributed to three important issues. STEM education (a) pursues answers to the global economic trials that many nations face, (b) identifies the increased need for STEM literacy for resolving global technological and environmental issues, and (c) concentrates on the knowledge necessary to develop workforce skills required in the twenty-first century (Ritz & Fann, 2015). STEM education has evolved into something more important than providing students with information about science, technology, engineering, and mathematics. It has become a technique that sparks interest in the pursuance of both learning STEM and seeking employment in a STEM-related career (Hall & Miro, 2016). In a 2010 account to the President, the President’s Council of Advisors on Science and Technology (PCAST) stated that all students, especially those who are underrepresented, such as women and minorities, should be proficient in STEM. To satisfy this need of representation, new approaches must be established to motivate more students to become interested in STEM. Studies have shown that students who participated in a math-infused, engineering and technology education program experienced an increase in math performance compared to those in a traditional math setting (Burghardt et al., 2010). The results of this study also indicate a positive effect on attitudes toward STEM curriculum and STEM-related careers. Other findings suggest that students participating in engineering projects experience improvements in interest and attitude. For example, a study by High, Thomas, and Redmond (2010) concluded that students who had completed such projects reported an increase in math and science confidence, interest in pursuing a career in engineering, awareness of the field of engineering, and improved understanding of math and science coursework. These findings have confirmed the need for advanced, experience-related methods to STEM education to offer opportunities that spark students' STEM interests and to equip them with skills necessary for the 21st century workforce.

STEM Careers

A recent study conducted by the American College Testing service (ACT) found a significant deficit between student interest in STEM subjects and the initiative to take the difficult courses required of STEM majors (ACT, 2015). Other results of the study concluded that students who are interested in STEM majors and pursue the STEM path in college are not prepared to succeed in the rigorous math and science classes. This leads students to become discouraged, and although interested in STEM, the choice to pursue a non-STEM major is made.

The U.S. Bureau of Labor Statistics predicts that, during the period of 2012–2022, employment options in science and engineering professions will grow by 14.8%, compared to 10.8% for all occupations (NSF, 2016). The current trend predicts that over the next decade, 1 million additional STEM graduates will be required. Considering the data that supports the need for STEM careers and the growth potential present in the field, the number of US college students majoring in STEM subjects is infinitesimal when compared internationally. In 2003, only 4% of U.S. college graduates majored in engineering compared to 13% of European students and 20% of students in Asia (Dugger, 2010). According to a report by the U.S. Business Roundtable (2005), if this trend remains, more than 90% of all scientists and engineers will live in Asia. Current projections predict that most high salary jobs in the future will require a mastery of science and mathematics skills. Furthermore, the mastery of science and mathematics is associated with college retention and success, economic stimulation, national security and innovation, and the ability to compete in the global market (Business Roundtable, 2005).

According to research, one reason for the lack of the pursuit of STEM careers is that student exposure to STEM career possibilities is not occurring soon enough. This lack of exposure leaves the student misinformed and unable to make an educated decision concerning a career path (Christensen & Knezek, 2017). Strategies used to spark an early interest in STEM and a possible STEM-related career include project-based and hands-on learning where students can perceive the relation in their own lives. One study concluded that many students do not view science as something relevant. Relatable learning opportunities are necessary for them consider a science career as a feasible option (Christensen & Knezek, 2017).

Integrated STEM Education

STEM education builds upon the foundation of theories of curriculum integration using two standpoints. One viewpoint is that STEM education permits teachers to integrate interrelated subjects without overlooking the exclusive attributes, complexity, and rigor of their core discipline. However, there is a gap between the methods by which STEM subjects are taught in schools and the knowledge, skills, and beliefs required for STEM education. Reducing the gap between contemporary teaching practices and the actual skills needed for STEM education is dependent upon the effectiveness of STEM teachers to successfully shift from the departmentalized model of teaching to an integrated teaching model (Corlu et al., 2014). The research on teaching integrated STEM provides a good foundation of instruction. With the help of educational institutions and federally funded programs, the support for STEM is growing. Rising teachers are now being taught about STEM integration in teacher preparation programs as undergraduates (Stohlmann, Moore, & Roehrig, 2012). This leaves veteran teachers with the task of seeking out training independently. A question that teachers tend to ask is "What does STEM look like?" From an educational standpoint, the integration of STEM can be performing a variety of activities. Typically, this includes the replacing traditional style lessons of lecture-based teaching with deeper, project-based approaches (Breiner et al., 2012). Successful integration of STEM is largely determined on the teachers' understanding of the content. Many teachers, especially those at the elementary level, discover gaps in their own content knowledge (Stinson et al., 2009). Research by Zemelman, Daniels & Hyde (2005) on best practices for integration of STEM has provided a list of 10 methods for teaching math and science: the use of manipulatives and hands-on learning, cooperative learning, debate and inquiry, questioning and speculations, using evidence, writing for reflection and problem solving, use a problem-solving approach, integrate technology, teacher as a facilitator, and use assessment as a part of instruction.

Teachers can also supplement their pedagogy by focusing on making real-world connections, representations, and misconceptions. One of the advantages of using an integrated STEM curriculum is that these practices naturally gravitate toward STEM activities. These activities permit teachers to make interdisciplinary connections and facilitate "big idea" thinking by the students (Stohlmann, Moore, & Roehrig, 2012). Big ideas refer to interdisciplinary concepts that can be linked into one whole concept. These ideas are essential to the understanding of STEM across multiple subjects, and when combined, provide models of the natural world.

Teachers' self-efficacy plays a major role in effective integration of STEM. An optimistic belief in one's capability to deal with obstacles improves the ability to create constructive ways of coping. Self-efficacious teachers would be less threatened by the demands of daily teaching compared to teachers who have feelings of self-doubt and lack confidence in their ability to perform (Schwarzer & Hallum, 2008). Teachers who are not confident in their ability or their knowledge of STEM have a difficult time delivering quality instruction. This lack of confidence is related to a decrease in motivation of students, lowered self-esteem, negative class culture, and lower student self-efficacy. Studies have also suggested that a teacher's self-efficacy is related to the sense of satisfaction in career choice (Stohlmann, Moore, & Roehrig, 2012).

Materials Needed for Integrated STEM

Effective STEM integration will require numerous resources for students to discover and retest real-world problems through the design process. These materials can include building equipment such as saws, hammers, measuring devices; electronic materials such as computers, design software, robotic equipment, and calculators; other design materials such as cardboard, glue, cardstock, and styrofoam. These materials provide students with a better understanding of technology. A common misconception is that technology must be electronic and underprivileged schools are reluctant to integrate STEM because of anticipated cost. A broad definition of technology is anything that makes life easier (Stohlmann, Moore, & Roehrig, 2012). For students to receive an authentic STEM learning experience, a product must be produced through the design process. A STEM project does not have to include all four disciplines but should focus on real-world connections and problem-solving.

STEAM

The value of the arts within STEM disciplines has been recognized but is often not the focus in US education. The concept of STEAM education is developing as a model of how traditional boundaries between academic subjects can be removed to structure science, technology, engineering, arts, and mathematics into an integrated curriculum (Connor et al., 2015). It is a common misconception that scientists and engineers lack creativity. Creativity is defined as the cognitive ability to imagine unique ideas and see the connection between ostensibly unrelated things, while innovation is defined as the process that transforms those formed ideas into something of value. Design and creativity are vital foundations of the successful mathematician, scientist and engineer. This link is currently missing from many STEM programs, leaving students' creativity underdeveloped. The arts are incorporated within numerous STEM careers. For example, science and mathematics models are tools used in practice daily by cartographers, carpenters, architects, engineers, and digital animators. Within these careers, there is a solid relationship between technology, science, and design. STEM is relative to the creative arts in fashion industry, industrial design, interior design, and the creative arts applies to STEM through advertising and promotion, music, and model making. Models of mathematical structures can be used to create art and imaginative models. These models can also be used to elucidate difficult concepts of mathematics. The development of video game graphics incorporates a wide range of fields from STEM and the Arts (Hogan & Down, 2016).

Art-infused STEM curriculum is problematic for teachers to implement without straying away from standards-based instruction (Henricksen, 2014). Incorporating art into the STEM disciplines can be accomplished in several ways. Some recommended instructional strategies include models and tools such as visual representation, model-centered learning, community-based learning, and storytelling (Ge et al., 2015). For example, during the design process, students can apply design and decoration to a product that was created during the challenge. Also, the use of computer graphics to create logos or designs to include in the presentation of their findings incorporates the creative process. While still using engineering design, students can improve the appearance, design, and usability of a product created during a STEM project (Jolly, 2014). A suggested model for STEAM learning is that learning occurs on four different levels: 1) the accrual of frameworks of information, 2) the formation of connections among people and organizations, 3) the varying perception of self as new knowledge and skills are espoused, and 4) other people's shifting ideas of the learner as those new competences are acquired. It assumes a creative environment that is not inhibited by organizational parameters. The teacher's role is to be an overseer of talent, not a creator of ideas. Subsequently, the teacher/school has a duty to pull together materials to maximize the talents of the student. Learning happens over an irregular time span. Instead of semesters, academic years, quarters or fiscal years, learning is developed over moments, decades, and lifetimes. Also, financial/career benefits may not be instantaneous or may occur outside traditional courses. Learning is endlessly increasing and not confined to archetypal restrictions. It involves the student asking questions, which will enable him/her to develop his/her own direct and indirect views of whether the experience is worthwhile (Radziwill et al., 2015).

Encouraging students' participation in the arts can yield benefits such as promoting creativity and fostering spontaneity and self-expression, which leads to an increase in creative products. Art-related activities are also an effective method to introduce children to the basic concepts of mathematics and science. Students can collaborate and participate in the design process while improving problem-solving and decision-making skills. These advantages suggest that the integration of art into STEM can help students achieve 21st century skills and improve learning within the STEM domains (Ge et al., 2015). Between 1998-2010, four databases from the US Department of Education and the US Department of Labor were examined (Catterall, Dumias, & Hampden-Thompson, 2012). The results concluded that students who were exposed to art-related experiences were more likely to attend college although 71% of the 18,000 participants were from low socioeconomic backgrounds (Zhbanova, 2017).

STEM Education in Early Childhood

The recent attention surrounding the lack students pursuing STEM-related careers in the United States has prompted the focus toward developing STEM initiatives in American schools. While many programs exist for middle and high school students, there are fewer opportunities for those students in elementary school. Research indicates that early exposure to STEM programs and activities promotes positive student perception. By capturing students' interest early, the likelihood that the students complete the coursework necessary to enter college STEM programs is higher. Because of the *Partnership for 21st Century Skills* initiative, the importance of providing early exposure has been brought to the attention of educators. Engineering concepts, advanced inquiry, and math concepts are being integrated into elementary curriculum. Elementary teachers require support to include hands-on and inquiry-based activities in their lessons to aid in the teaching of abstract concepts. These types of lessons should not be withheld until middle school. Elementary students possess the cognitive skills to participate in problem solving activities which in turn increases the interest of pursuing STEM content. Young learners become engaged in STEM lessons and become more confident in their abilities to be successful in advanced science and math courses in high school. Although elementary students respond well to STEM lessons, many elementary teachers are not equipped with the pedagogical expertise in scientific inquiry and technology design. Due to the strains of standardized testing in America, the development of scientific pedagogy in elementary schools is inhibited. Students learn about scientific theory and the nature of science instead of performing scientific investigations. As a result, the students must rely on others' conclusions rather than explore themselves. Standardized tests require teachers to deliver a structured science program in schools focusing only on knowledge acquisition. Student motivation suffers and the desire to pursue science is lessened.

Providing exposure to elementary students may be the key to ensuring the success of STEM programs in America (DeJarnette, 2016).

To improve STEM learning, the selection, preparation, and licensure of elementary school teachers should be considered. The methods used to select teachers are incompatible with goals for economic growth, increasing interest in STEM careers, and innovation. Not only are these teachers poorly equipped to teach science and math effectively, they have very little interest in STEM. Polices for admission into teacher preparatory programs need reform. Admission criteria should include more math and science course requirements, state licensure requirements as well as a more selective application process. Applicants to these programs should be held to higher standards, particularly those that demonstrate a proficiency in math and science content. These programs should provide rigorous instruction and teacher candidates must perform at the same high levels expected of their future students. Better prepared teachers can provide students with the skills needed to succeed in more advanced courses. In addition to low performance, a child who struggles in math is led to believe that he/she is not a "math person." However, struggling readers are not taught this way. Students are taught the importance of reading and encouraged to practice and improve. Many teachers lack confidence in math which puts them at a disadvantage when it comes to building the confidence of their students (Epstein & Miller, 2011).

Project-Based Learning

Research studies have found that traditional educational lecture may promote memorization of facts but typically fails to produce the understanding of material (Wang et al., 2011). In recent years, educators have tested numerous teaching methods to determine the most effective technique of delivering instruction and encouraging student interest. Methods such as flipped learning, cooperative learning, problem-based learning, and project-based learning are popular topics in education and associated with integrated STEM education. These constructivist teaching strategies are used in classrooms to inspire students, promote engagement and participation and move the focus of learning from the teacher to the student. According to Filippatou and Kaldi (2010) project-based learning is the most popular of these strategies. This learning system permits students to improve their critical thinking skills, which allows them to become involved in research and decision-making processes. Students also develop processing skills and the ability to form relative questions while drawing conclusions from research. Project-based learning fosters the collaboration process between students and promotes teamwork. During the process, the teacher acts as a facilitator, guiding students through a step-by-step problem-solving process, typically: identify the problem; develop a strategy; do a 'reality test' on the idea; reflect on the plan while designing and completing the project (Mahasneh & Alwan, 2018). The teacher establishes well-defined parameters for the project and identifies the learning objectives. Project-based learning creates some apprehension among teachers because it requires the teacher to step into an unfamiliar role as a facilitator. The problem-solving process consists of cooperative learning. Therefore, students accrue more responsibility for both their social skills and their academic skills (Myeong-Hee, 2018). According to Allen (2015), there are nine necessary elements of the implementation of project-based learning: 1) academic learning outcomes- students are taught and achieve measurable results in subject-specific disciplines; 2) incorporation of 21st Century Competencies- students are taught and assessed on creativity, communication, collaboration, and critical-thinking; 3) Tangible outcomes- students develop products that can be used beyond the classroom setting; 4) Focused inquiry- students examine "real world" issues; 5) Focusing question(s)- questions drive the inquiry process and can be answered at the end of the project; 6) Engaging context- there is an issue of interest to students that can be researched; 7) Student voice and choice- students have the opportunity to express their thoughts in the decision-making process; 8) Drafting and critique- opportunities are provided for students to revisit their work and make changes; 9) Adult world connections- students work with experts and primary resources

Benefits of Project Based Learning

There are numerous advantages that can be attributed to the implementation of project-based learning in the classroom. It is described as an outlet for every student to experience success because of its ability to develop intrinsic motivation and cultivate a range of knowledge and skills (Tamim & Grant, 2013). Students are exposed to various domains through different activities and develop positive feelings, such as self-esteem and enhanced confidence. For example, Neo and Neo (2009) determined that student interest, critical thinking abilities, presentation skills, and the ability to work as a team were improved when working on a project-based learning activity. Also, the amount of knowledge acquired by the student dramatically increased, allowing the student to attempt to interpret the information rather than report the facts. Teachers also reported positive gains from the implementation of project-based learning. The benefits most reported included the building of critical thinking skills, learning and understanding the subject matter, and the learning of information beyond the content level, thus allowing the learning to become more varied and personalized (Myeong-Hee, 2018). This differentiation also produces intrinsic motivation and increases the academic output of the student. Research supports that students who learn through projects perform better on standardized assessments than students who learn by traditional means (Bell, 2010).

Technology is an effective method to enhance the creativity within the established parameters. When technology is used efficiently, students become engaged because it allows them to access their prior knowledge of computers. During the research phase, students can access the internet or other applications and discriminate between reliable and unreliable sources. The students may also use various technologies to display their findings. This allows students to share their findings and challenges, but to also experience the technologies used by others, adding to their own previous knowledge. This brainstorming method promotes creativity and encourages the students to think creatively.

Challenges of Implementation

When teachers decide to implement project-based learning within their classrooms, they might encounter some obstacles. Among these challenges are taking on the constructivist approach, using new instructional strategies, selecting an appropriate curriculum or topic, designing an activity, assessing the success, and the nature of collaboration (Myeong-Hee, 2018). Teachers' struggles can often be attributed to finding the balance between student control and teacher control. Teachers find it difficult to transition from delivering knowledge to facilitating the acquisition of knowledge. They must be able to accept a shift in their role and become comfortable implementing student-based pedagogies, which takes time. The amount of time leads teachers to become discouraged and feel that the project is unsuccessful. In addition, teachers need to be tolerant of vagueness and flexible enough to allow the dynamic environment necessary for a student-centered approach to learning. Surveys indicated that a common concern of teachers was fear of not having enough time to cover the required curriculum because of the amount of effort required to transition students from traditional learning to student-based learning. This was especially true in elementary grades (Tamim & Grant, 2013). Also, the fear of the loss of control over the topic and the behavior of students was reported. As a result, the teachers deemed it difficult to give the students enough time to complete the project and felt the need to build the students' skills before beginning. To discern the results of project-based learning, the teacher must be motivated, open to change, and allow for flexibility during the learning experience.

When adopting new instructional strategies, it is important that teachers receive adequate professional development to become comfortable. It has been determined that even when teachers show enthusiasm and participate in training workshops, difficulty implementing new strategies still occurs (Tamim & Grant, 2013). The struggle to shift from an accustomed teaching method to a new student-centered method is overwhelming and many teachers do not fully implement project-based learning. Even the most experienced teachers needed additional guidance. Therefore, teachers implementing new methods need adequate training along with appropriate resources to overcome the obstacles preventing them from fully implementing project-based learning.

For some teachers, the benefit of technology poses a challenge. Technology is important for the implementation of project-based learning, but integration is difficult because student computer access is limited. In these situations, the teacher must take valuable class time to educate students about the machine rather than facilitate the problem-solving process (MacMath, Sivia & Britton, 2017). Factors outside of the teachers' control, such as school culture, educational policy, confines of standardized tests, and technology support can also impact implementation. Research shows that implementation is most successful when it is supported by administration, used by multiple teachers within the same school, and is part of a school culture that is student-centered).

STEM-Focused and Comprehensive Schools

Policymakers have identified an option for increasing the number of STEM workers as creating specialized STEM schools. The environment of these schools can be described as unique with expert teachers teaching an advanced curriculum with opportunities for internship and immersion (Erdogan & Stuessy, 2016). There are three categories of STEM schools, all serving a different pool of students. The first, selective STEM schools, serves students with high-achievement and an interest in the pursuit of STEM knowledge. These schools have criteria to be met before admittance. Inclusive STEM schools serve similar students but have no admission requirements. STEM-focused career and technical education (CTE) schools serve students who are at risk of dropping out and admit students based on no criteria. The mission of these schools is to prepare students to enter STEM careers, especially those from underrepresented populations (Erdogan & Stuessy, 2016). Ten crucial components of building opportunities for students have been identified and STEM schools work to incorporate them completely. Strong courses are offered in all four STEM disciplines and technology and engineering are integrated into non-STEM disciplines. The STEM courses accentuate instructional practices supported by research for active teaching and the immersion of students in STEM content, processes, and habits of mind and skills, thus reforming instructional strategies and incorporating project-based learning. The school's use of technology changes the relationship of students, teachers, and knowledge. Blended and informal learning is used throughout the school year including apprenticeships, mentoring, afterschool clubs, and projects. Students can connect to the business world through internships and projects that occur outside of the school day. The teachers are well-prepared and possess extensive content knowledge along with practical experience in STEM fields. The mission of the school is to prepare students for STEM and places an emphasis on recruiting students who are from underrepresented groups. The hierarchy of administrative structure includes strength and organization of school leadership and principal, the hiring and recruiting of quality STEM teachers, arrangements and contracts with the community, and school-level data-driven decisions concerning education. Lastly, the school provides support for underrepresented students through bridge programs, tutoring programs, extended school day, extended school year, or looping to strengthen the transition of the students into STEM careers (Peters-Burton et al., 2014).

After-school STEM Programs

To promote students' curiosity in STEM disciplines and to support STEM literacy, numerous initiatives and efforts have been developed and executed within public schools. The US government started a program, "Educate to Innovate," with the goal to boost student involvement in STEM-related activities and to rouse an interest in STEM-related careers. Afterschool programs and summer programs are an imperative and growing part of STEM instruction reform in the United States. An estimated 8.4 million children join these programs each year, many from populations that are under-represented in STEM fields and careers (Krishnamurthi, 2014). Programs that enhance traditional schooling have become popular in education communities. After-schools activities provided the opportunity for individuals to become involved in activities that foster the skills necessary to construct their own resolutions to everyday problems presented in a simple context. Programs such as science clubs are associated with visits to museums, zoos, planetariums, national parks, and natural settings. Other types of after-school activities include robotics, science fairs, Science Olympiads, and Mathematics Olympiads. These programs are a means to develop social skills, set life goals, and encourage educational achievement as well as develop a better understanding of scientific concepts, process, and procedures. Students learn how to work together and connect with their peers and teachers outside of a regular classroom setting. Stimulating after-school activities allow them to obtain scientific inquiry skills, develop scientific reasoning abilities and advance their communication skills. Students who attend extracurricular STEM activities are more motivated to join competition-oriented science fairs and Science Olympiads. Participants in these activities are informed that they will compete with other students from other communities throughout the semester. This competitive atmosphere encourages students and their teachers to build cooperative partnerships with graduate students and scientists, thus developing multi-memberships. This bridge connects students to individuals in different communities and provides opportunities for assistance with accomplishing their goals (Sahin et al., 2014).

STEM related activities such as Robotics, MATHCOUNTS, American Mathematics Contest (AMC), Science Olympiad, Science Fair, and University Interscholastic League (UIL) are popular choices for after-school programs. Robotics activities include designing, programming, and problem-solving activities involving robot models controlled by computer software. Students work as a team to build, design, and test their models to be presented to an audience during a competition. Activities such as MATHCOUNTS are designed to increase students' achievement in mathematics as well as teach them to establish a connection between mathematics and daily life, parental and peer relationships, school, and society. In MATHCOUNTS activities, group members practice strategies necessary to identify problems, devise plans and solutions, and incorporate the decision-making process. These tasks build problem-solving skills while fostering social development also. American Mathematics Contest strived to increase interest in mathematics and enhance problem-solving skills. Activities included inclusive approaches to elementary and original critical thinking strategies including plane and transformational geometries, proofs, and number theory. Although many schools have science fairs, Science Olympiad provided an opportunity for participants to compete among other schools using projects approved by a committee. Selected groups were then chosen to compete in a Statewide Olympiad held at a university campus. Groups were to then present their projects in a professional setting to judges consisting of faculty members, researchers, and graduate students in the field. STEM-related after-school program activities differ from regular classroom activities allowing students to move their focus from standardized tests to cognitive-centered activities. These activities appeal to students more when compared to completing quizzes and worksheets. The open-ended nature of the activities allowed for more uncertainty and commitment, encouraging students to engage in the task (Chittum et al., 2017). Data analyses revealed that STEM-related afterschool program activities amplified participating students' interest in STEM majors and inspired them to pursue science and engineering related careers because the activities were considered more interesting and inclusive. The second reason was that the school had established a mission to encourage its students to pursue their occupation in STEM field post high school (Baran et al., 2016). Implementation of afterschool programs are not without challenges. Providing high-quality activities requires high-quality staff. Many educators leading these programs lack the science expertise and experience to provide rigorous, meaningful instruction (Freeman et al., 2009).

Funding from federal initiatives has significantly provided the necessary materials for STEM programming. For instance, the Noyce Foundation, a private foundation, heavily supports afterschool STEM programs through partnerships. A C. S. Mott Foundation-Noyce Foundation collaboration is presently active in 16 states and continuously expanding as the number of afterschool programs grows. Noyce also invests in "Project LIFTOFF," which focuses on developing STEM programs in the Midwestern states. This initiative has encouraged many school districts to combine funding with local community learning centers to deliver high-quality afterschool STEM opportunities. As schools, communities, and parents discuss solutions to offer further learning opportunities for children, afterschool and summer STEM programs provide a model that satisfies this need. Multiple research studies have shown that afterschool programs that are well aligned with the school day and have strong connections to the community have ideal advantages for kids.

There is a great need for high-quality afterschool and summer STEM programs to assist the national priority of STEM education reform. This requires action from all stakeholders to achieve success. Federal and state education policies must guarantee that afterschool and summer programs are included in STEM education initiatives if they are to become a long-term, sustainable opportunity. Also, afterschool programs must apply several approaches to become effective deliveries of STEM education. They must pledge to offer learning opportunities and then provide adequate professional development in STEM disciplines to staff. This will guarantee that high-quality STEM educators are available. A local organization such as a science museum, university, as well as other science and math institutions, is often a requirement for distributing information and organizing professional development efforts and other STEM programming needs for afterschool (Paulson, 2013). This may require seeking partnerships with STEM-rich institutions, such as science museums and universities, as well as other science and math centers in various states. Intermediate organizations and large networks must endorse existing curricula to avoid wasting materials on ineffective programs (Wilkerson & Haden, 2014). The field must agree on and adopt a vision and set goals for the education of youth. Relevant STEM learning that spreads past single experiences are essential. Afterschool and summer programs must strive to offer consistent, dependable programming in STEM disciplines. Additionally, programs must provide a variety of learning experiences that apply to children in middle and high school to attain the maximum effect from STEM programming. Local employers and STEM professionals who would like to support or become involved in afterschool programs should familiarize themselves with the STEM ecosystem of their region. The afterschool STEM field has its own culture and philosophy, and it is important to be aware of the differences (Krishnamurthi et al., 2013).

Flipped Classroom Model

A flipped classroom is an approach to teaching in which the pedagogy is delivered first outside of class time. The strategy consists of two key components: (1) the use of computer technologies and (2) the involvement of interactive learning activities. Students are exposed to new material by pre-recorded videos using technology, text readings, or research assignments. The time spent during class time is used for inquiry, assessment, and application. The instructor facilitates learning by guiding individuals or groups through course material. This approach is thought to better meet the needs of the learner by freeing up class time for active learning strategies. The main goal of flipping a classroom is to encourage deeper, richer learning experiences when the teacher is present for guidance. The emphasis is placed on higher-order thinking skills and complex application to problems. The goals of a flipped classroom are very similar to the goals of STEM education, making it an effective teaching strategy for teachers wishing to enhance the critical thinking skills of their students (Cabi, 2018).

Teachers roles in a flipped classroom environment differ from those performing in a traditional classroom setting. The responsibility of the teacher is shifted from directly teaching to developing a student-centered activity to enhance the learning process and create a deeper understanding of the material. The responsibility for learning the material is placed directly on the students. The flipped classroom model improves learning outcomes, supports higher-level thinking, and supports technology use for teaching outside of the school. Students are now considered digital native learners who are accustomed to daily use of technology and the flipped classroom model is more suitable for their learning needs. The application also boosts motivation and improves student learning performance (Cukurbasi & Kiyici, 2018).

There is a need for more effective pedagogy delivery within the subjects of science, technology, engineering, and mathematics. Instructional approaches designed with student engagement and achievement in mind can benefit students by involving them in various aspects of the problem-solving process. This process includes the essential skills of defining and understanding a problem, researching for information, delineating new terms and analyzing relationships between variables, hypothesizing or planning solutions to the problem, and checking that the proposed solution is consistent with all elements of the scenario (White et al., 2017). The flipped classroom approach provides a teaching design that assists students with the development of these skills. The pre-learning that students engage in before class can help with the development of language of the new content and understanding the problem. In-class active learning approaches where students apply knowledge and analyze problems have been proven to improve student performance. Tasks that require students to create diagram representations of their understanding, such as concept mapping, can assist with the comprehension of the connection between variables. A flipped classroom model has provided positive results for the retention of STEM-related material. Students spend more time engaging in course content to produce their own summaries and explanations. The increased time and engagement results in increased performance on exams. Students also respond well to the flexibility of accessing course material on various electronic devices (Cheryl and Stephen, 2013).

Both teachers and students benefit from the implementation of a flipped classroom model. For teachers, the movement of content delivery outside of the course frees up time allowing for more energy to be devoted to observation, feedback, and assessment. Students can take ownership over their learning and receive direct support and guidance during class. Flipped learning enhances discussion and classroom interactions by permitting students to individually control the out-of-class content and apply the knowledge during communicative activities during class. Among the benefits, challenges also exist. Flipping a classroom takes increased time to set up learning tools and equipment, provided that the required technology is available. Many school districts lack the appropriate equipment to successfully implement a flipped model. Schools that can supply the necessary technology may face the challenge of lack of student access to internet and technology at home. Students who are not familiar with technology find content difficult to navigate and require additional support to successfully access the lessons. Teachers who decide to implement a flipped model must devote time to creating instructional videos and developing meaningful activities to enhance critical thinking skills during class time. However, these activities and lessons can be reused from year-to-year, which saves time after the initial execution. Generally, flipped learning works best with motivated students who are willing to spend time completing additional online activities at home (Bauer-Ramazani et al., 2016).

Teacher Training and Retention

Problems associated with recruiting, supporting, and retaining quality teachers in the STEM disciplines have been well documented in literature (Beaudoin et al., 2013). Findings suggest STEM teachers request additional instruction and wish to increase content knowledge.

The need for additional training may be due to the popularity of STEM teachers achieving alternative certification. An increasing number of K-12 teachers are entering the education field from other areas and receiving certification through alternative programs. By not completing a traditional teacher preparatory program, they are less exposed to formal training in teaching strategies and content. There is a significant difference in the confidence levels of teachers who complete alternative programs compared to those who completed a traditional preparatory program. These differences can significantly influence teacher effectiveness. Quality professional development programs can enhance teacher efficacy in content knowledge and teaching strategies.

For those teachers who complete traditional preparatory programs, most provide little information on STEM education. There is limited professional development and the training offered is not based on the needs of teachers. The crisis of finding teachers for these subjects is now being seen in the number of students interested in the courses. The key to proper integration of STEM is to educate teachers regarding technology (Jenlink, 2013). American society has become saturated with technology during the Digital Age. Most employment opportunities require basic knowledge of how to operate relevant technology. Students will require a solid background in STEM to be productive members of the workforce. To better prepare students, it is imperative that technology training become a priority for pre-teachers and veteran teachers, regardless of content area. STEM literacy training should be considered for the following six areas of teacher preparation. During STEM and non-STEM teacher programs, the need to be prepared to teach STEM should be addressed. Student knowledge is directly related to teacher knowledge. If teachers are equipped with 21st century knowledge of technology, the students will be equipped as well. There should be rigorous and relevant pre K-12 STEM education requirements established in teacher preparation programs to create a pathway from preparation to the workplace. The more skills teachers develop during training, the more comfortable they will feel implementing these skills in the classroom. Preparatory programs should provide relevant technology and be prepared to respond to accelerating change within the field. By integrating technology, teachers can advance educational strategies and bridge the gaps between content-area specific and teacher preparation program. Professors competent in STEM teaching and learning should be available to provide first-hand experience of how STEM looks in the pre K-12 education system. Teacher preparation should be focused around STEM literacy, developing cognitive skills, critical questioning, aesthetic appreciation, innovative and creative design, and social interaction. Models of integrated STEM should be provided to teachers of all disciplines that focus on rigor and relevance. This guarantees that teachers leaving the program are STEM literate and that every student they encounter will be STEM literate upon graduation from high school (Jenlink, 2013). The importance of STEM literacy in teacher programs is intensified due to the increased need for training of teachers already teaching in STEM classrooms.

Student Engagement

One of the most noted benefits of integrated STEM education is the effect on student engagement. Researchers, educators, and policymakers are focused on increasing student engagement to remedy underachievement, boredom, alienation, and high dropout rates (Fredericks & McColskey, 2012). Student engagement refers to a student being actively involved in the classroom and his own learning (Hao, Yunhuo, & Wenye, 2018). Student engagement can be defined as the concern with the interaction between the time, effort, and other relevant resources invested by both students and their institutions intended to enhance the student experience and improve the learning results and growth of students and the performance, and reputation of the organization. (Trowler, 2010).

Research has demonstrated that students become more disengaged during the transition from elementary to middle school, with some estimates that 25–40% of youth showing signs of disengagement (Fredericks & McColksey, 2012). Disadvantaged middle and high school youth experience the harshest consequences of disengagement. These students are at risk for dropping out, which limits their employment opportunities, thus increasing their risk for poverty. Impoverished citizens experience poorer health and are more likely to be involved in the criminal justice system. Annually in the United States, approximately 1.25 million children, or 7000 per day, leave without a high school diploma (Dugger, 2010).

If a student is engaged, he/she is more involved in the lesson, but not necessarily participating. Acting without the feeling of engagement occurs mainly due to compliance or involvement. As discussed by Bloom in 1956, there are three dimensions to student engagement. Students who are behaviorally involved would naturally adhere to behavioral norms, such as attendance and participation, and would demonstrate the absence of unruly or undesirable behavior. Secondly, students who are involved emotionally would experience positive reactions such as interest, enjoyment, or a sense of belonging. Also, cognitively engaged students would be devoted to their learning, would seek to go beyond the requirements, and would find enjoyment in being challenged (Trowler, 2010).

Five facets form the foundation of the National Survey of Student Engagement (NSSE), the annual survey conducted among public and private higher education institutes in the US and Canada. Academic and non-academic aspects of the student experience should be composed of the following: active and collaborative learning, participation in challenging academic activities;

formative communication with academic staff; involvement in enriching educational experiences; feeling legitimated and supported by university learning communities (Coates, 2009).

Engagement not only positively affects teacher and school identity but has been shown to influence academic achievement of students who previously had poor grades and those who were at risk of dropping out. It is a reasonable concern for institutions to be troubled with student engagement or the lack of engagement. According to Krause (2005), the most concern should be expressed when students who should be receiving targeted aid in the form of student support, course advice from instructors, or peer support are not receiving this because they failed to engage when the opportunities were presented. These students are the most at risk for failure and unable to succeed. This lack of engagement should be targeted within the first year of study to prevent dropping out or withdrawing from the program. Engagement was determined to be particularly beneficial to groups of students least prepared for higher education, such as international students, students with disabilities, first-generation students, students from low socioeconomic backgrounds, students from minority religious groups, and racial/ethnic minority students. However, these students were more likely to view engagement as a negative process due to feelings of isolation, alienation or being overwhelmed (Trowler & Trowler, 2010).

Various methods are used when measuring student engagement. The use of surveys in assessment, especially surveys of student engagement, has experienced an intense growth in popularity over the past fifteen years (Pike, 2014). This method is practical for classroom use and can be administered to a large, diverse sample quickly, allowing for multiple opportunities for data collection in a short amount of time. Students are supplied with engagement-related items and select responses that apply to them. These items are generally not subject-specific but can be altered to fit a single discipline. This method is perceived as a flawed method because responses are considered subjective when compared to objective methods such as behavioral observation, including attendance and homework completion rates (Fredericks & McColskey, 2012). Also, students may not provide honest responses if the survey is administered by the teacher without anonymity. However, student self-reports can provide information about emotional and cognitive engagement that could not be assessed by observation. Another method used for assessing engagement is a teacher observation and rating scale. Different perspectives offer a more detailed result with the teacher reporting on behavioral and emotional engagement. This is also useful for younger children who may not be able to complete a questionnaire due to undeveloped literacy skills. Although an unstructured approach, student interviews are also a tool that can be utilized for assessment. Students can provide elaborate open-ended responses to describe their experiences. Researchers recommend the use of more than one method to achieve a result free from bias.

Gender Divide in STEM Careers

Although women comprise 57% of US college students, their representation in the STEM fields is affected the greatest by the declining interest in STEM majors (Shapiro & Sax, 2011). Evaluation of first-year college student shows that only 17.3% of women plan to major in a STEM field compared to 32.2% among men. This gender division is noticed especially in the fields of engineering, physical science, and computer science. The underrepresentation of women in these growing fields has economic consequences both individually and nationally (Shapiro & Sax, 2011). Women's economic opportunities and independence are hindered by the lack of technological skills. Also, with the demand for STEM graduates growing exponentially, the loss of the potential talent present among women puts the US at a further economic deficit internationally. Furthermore, the fields of science and technology benefit from a diverse workforce because of differing perspectives. By generating opportunities for more women to pursue and be successful in STEM fields, the diversity of the workforce will increase and as a result, more dynamic and complete research will be produced.

The most critical time for the development of interest in STEM subjects has been identified as the years spent in middle and high school. Kinzie (2007) determined that in 8th grade, pathways are created for women into STEM or out of STEM. Math achievement during this time is important because low math achievement in 8th grade may influence the number of math courses women take in high school. If women become discouraged early in their academic careers and take fewer math classes in high school, they are not adequately prepared to succeed in college-level math and science courses. In a qualitative study of more than 450 students from seven institutions, Seymour and Hewitt (1997) concluded that inadequate preparation in high school science and mathematics courses was a determining factor for those who withdrew from science, mathematics, and engineering majors. A larger percentage of women reported feeling inadequately prepared when compared to men.

The culture of science and math classes has also been identified as an influence of the decision of women to pursue STEM majors. Competitiveness is a unique quality and many women do not perceive competition as a meaningful way to receive feedback and may even find it offensive (Shapiro & Sax, 2011). The large, lecture format of college STEM courses adds to the already intense competition for grades. Also, this method is used as a weeding out tool to facilitate the self-removal of underperforming students from STEM majors. This weed-out system also discourages students from working together and promotes the idea that they are responsible for their own work. Furthermore, science faculty are more likely to grade on a curve, which adds to the competition for grades. Surveys of students, both male and female, have shown that science and engineering professors are described as unresponsive, not dedicated, and unable to motivate when compared to the faculty of humanities and social sciences. Classroom climate can deter women from enrolling due to potential feelings of depression about their work and lower self-confidence in their ability to perform. Evidence shows that science faculty have yet to utilize collaborative teaching techniques and active learning practices and instead focus on the delivery of content through lecture.

Additionally, faculty can have a significant impact on women and influence the choice to pursue or continue the path to a STEM career. Positive interactions with science faculty promotes student interest and provides a role model to encourage perseverance. The underrepresentation of women in STEM is not only observed at multiple levels in education, including high school, college, and graduate school, but in academic positions as well (Jackson, Hillard, & Schneider, 2014). Female role models are more likely to influence female students than males, however. Regrettably, due to the lack of representation of women in STEM fields, female students are less likely to encounter a female faculty member to utilize as a mentor. Blickenstaff (2005) suggested that a low proportion of women in a discipline probably sends a message that the discipline is unattractive to women and should be avoided. It is important for female students to be exposed to women who are successful in STEM fields while also juggling the responsibilities of life. By having a professional role model, the confidence of women students increases, and they can perceive the possibility of becoming successful within their major and a possible STEM career. Some discriminatory practices have been documented in STEM classes. In a survey by Wasburn and Miller (2004), approximately one-third of female respondents felt their technology professors treated female and male students differently.

Additionally, 20% of the female respondents felt uncomfortable asking questions in class, and one-quarter did not feel comfortable seeking assistance from their technology professor outside of class, which discouraged their continuation of a STEM major.

In addition to educational settings, the interactions and experiences of women outside the classroom can influence the decision to pursue a STEM career. Women consistently express lower feelings of self-worth when compared to men even if their academic performance is equivalent (Shapiro & Sax, 2011). This lack of self-confidence can deter women regardless of cognitive and academic gains. Contributing to these feelings of low-esteem, women tend to feel unwelcome in the field of STEM. In their study of computer science students, Margolis, Fisher, and Miller (2000) found that women lost interest in computer science because they did not fit the mold of a stereotypical computer scientist. Piatek-Jimenez (2008) also determined that the stereotype of mathematical careers influenced women's interest in careers as mathematicians.

International STEM

Fewer than one in seven students in the United States obtain a degree in science or engineering, compared to one out of every two students in China and two out of every three students in Singapore. Every few years as progress reports are released, policymakers call for educational reform because of the fear of decline in student achievement in math and science and potentially falling behind other countries. The difference in international STEM programs is that losers are not required for there to be winners (Heilbronner, 2014). Researchers from multiple nations use various methods of measuring educational impact on students, especially in the fields of math and science. To compare international STEM results to those of the United States, test scores and the number of advanced STEM degrees can be used as indicators. Two international assessments that can be used are Trends in International Mathematics and Science Study

(TIMSS), and the Program for International Student Assessment (PISA). These assessments are influenced by factors outside of the classroom, including poverty, stability, and home life. In a 2011 TIMSS report, the outcomes of science and math were measured in 63 countries and 14 sub-components of nations, such as England. TIMSS assesses both content knowledge and cognitive processes. During the assessment, students are required to use critical thinking skills to apply content knowledge to explain a phenomenon. A typical 4th grade level TIMSS question might be to explain why plants do not consume food the way that humans do. TIMSS also assesses inquiry-based practices. Results for the 2011 TIMSS assessment indicated that students in Korea, Singapore, and other East Asian countries scored highest marks at both the 4th and 8th grade points. The United States' 4th grade ranked in 7th place and 8th grade in 10th place. The scores of 547 (4th grade) and 535 (8th grade) were significantly above the median of the scale, which is 500. When analyzing the distribution of scores, researchers noticed that the distribution of scores was much wider within the nations scoring below the midpoint than those that scored above the midpoint. This suggests that there are broader gaps in lower scoring countries between student sectors. These gaps can be attributed to differences in economic advantages, geography, and population. Parental income and education, resources at home, teacher preparation, and school safety all played a role in test results. STEM education might not appear in many countries, because it may not be fitting for the cultures of specific world regions, especially impoverished regions (Ritz & Fann, 2015). Students of nations that emphasize science and have adequate resources score higher on the TIMSS. PISA is the most respected of the international assessments. Every four years PISA is administered to 15-year-old students to assess literacy in reading, mathematics, and science. The 2012 results displayed similarities to TIMSS, indicating that in every tested nation there is an achievement gap between the socioeconomic advantaged and disadvantaged.

The second indicator of the quality of STEM education is the number of students who pursue an advanced STEM degree. Several established member nations of the Organization for Economic Cooperation and Development (OECD) have produced enough PhDs to flood the job market and are at risk for having no available jobs for additional graduates. In Japan, the United States, Germany, and Poland, the number of PhDs conferred has outpaced jobs available in the academic market (Heilbronner, 2014). Egypt, however, is struggling to produce PhDs. Frequently, these degrees are not conductive for research careers. In Egypt, students are more likely to use these degrees to enter civil service fields or private industry, not academia.

International Achievement Gap

The United States recognizes education as a necessity and spends 7.3% of its gross domestic product on education, more than all other countries except Iceland, Korea, Denmark, and New Zealand (Makel, et al., 2015). In the United States, teachers report spending 1,100 hours yearly on instruction whereas the global average is under 800 hours a year. Additionally, in the United States, most states mandate at least 180 school days per academic year. In India, school days are determined at the state level as well, but 180 days is the minimum amount of school days required. Most elementary schools in India average 211 days per year with over half requiring between 226 and 250 days per year. This significant time gap can create a large difference in academic achievement if continued for several years.

Another difference between international STEM programs and those in the US and similar countries such as Australia is that the STEM disciplines are considered appropriate for only those students who excel in science and mathematics. The high-performance countries in

East Asia have discovered that success in education is not based solely on talent but on the hard work that is invested. The belief that pre-disposed talent determines learning preserves the trend of low achievers. In China, Russia and some European countries, students are required to enroll in mathematics courses until the end of their school careers. Following graduation, many students continue with advanced mathematics. Countries that are considered strong in STEM have diverse economies, political and social cultures, and share common educational traditions. For example, school teachers are held with high regard, are better paid and have more opportunity for career advancement and recognition than teachers in less achieving countries. A notable example is Finland, where all teachers have a Master's degree, teaching is the hardest profession to enter surpassing that of physicians, and the strongest teachers are paid an additional stipend to work in low socioeconomic school districts serving impoverished families and students with the highest learning disabilities (Marginson et al., 2013). In China, STEM teachers receive salary increases for continuing discipline-specific professional development programs instead of seniority. To be promoted, China's teachers must show improvement in skill and their standard of work. These countries also have a strong commitment to the content of disciplines. Knowledge is the primary focus of teaching, not classroom management. STEM teachers are expected to be competent in their discipline and to teach in that field only. Additionally, the most successful countries have introduced active programs of restructuring in curriculum and pedagogy. The programs use problem-based and inquiry-based learning to make science and mathematics more engaging and relatable while placing and emphasis on creativity and critical thinking.

Finally, STEM-strong countries have established strategic national foundations for STEM policies that provide suitable environments for a variety of education cultivating activities, such as centrally driven and funded programs, including curriculum restructuring and new teaching standards, intensive university programs, the employment of foreign science talent and new doctoral cohorts; reorganized program initiatives and partnerships that link STEM activities in schools, vocational and higher education with industry, business and professions. Often, STEM programs are led, facilitated, or informed by institutes, centers or other agencies that have been explicitly formed to progress and resource the shared national STEM agenda (Marginson et al, 2013). Internationally, students spend more personal time on academics outside of the classroom compared to the United States. Increased study time is important because it is positively correlated with academic achievement. Over 94% of US secondary school students stated that they completed homework outside of school, with females spending an average of 7.5 hours and males 6.0 hours each week (US Department of Education, 2008). In India, the amount of time spent on homework is much higher, with males from urban areas spending 3.9 hours and females 2.9 hours each day. US students also report finishing less than half of what had been assigned, which would contribute to the lack of time spent on homework and partially explain the culture gap (Makel et al., 2015).

Internationally, one method does not satisfy the needs of all populations. Because of local and international situations, some countries have started to explore diverse teaching tactics within the mathematics and science subjects to advance student learning. High achieving countries like Korea and Singapore consistently emphasize the need to deliver STEM education for all and boost high achievement. China is also testing STEM education strategies. In Beijing’s Yew Chung International School, students are taught in both Mandarin and English languages within the same class by Chinese and Western teachers. The team teaching method is also present in science, mathematics, geography, and other subjects. In addition, mathematics is taught by one teacher explaining step-by-step procedures in English, while the second teacher demonstrates shortcuts for solving the same problems through the Mandarin language. These approaches have resulted in better understandings by students and higher student achievement (Ritz & Fann, 2015).

It is Russian tradition for all students to study mathematics until the end of their school careers. Specialty science schools are options for education with a strong emphasis on math and science competitions (Marginson et al., 2013). Japan continuously maintains high achievement by investing in super science high schools, but science and mathematics are no longer required until the end of senior secondary school. In Taiwan, students participate in an integrated science curriculum for all students until the end of year 11 before pursuing STEM and non-STEM programs. Taiwan is one of several school systems where the choice to pursue STEM is offered consecutively instead of simultaneously. Students find it possible to consider both options until the end of senior year and sometimes after the end of the first degree. To remain competitive with high-achieving STEM countries, the United States must develop a STEM policy outline around the need for a highly educated and innovative STEM workforce, STEM talent capable of substantial creative achievement and invention, and the need for all students to have STEM knowledge and skills. To make this possible, there are several objectives that should be considered. First, there is a need to fortify high-end STEM cohort size and ability. Educators should pay special attention to STEM-enthusiastic students by providing a more focused and more exciting STEM experience. This will encourage retention and pursuance of a STEM career. Next, address the need to secure more retention of high achieving year 11 and 12 STEM students at the higher education stage. These students are closer to making the decision of pursuing a STEM major during undergraduate studies. It is important to increase the number of students coming through the STEM pathway, especially the senior secondary students doing mathematics and one science subject. One way to increase the number of students is required mathematics through the end of year 11 or year 12 of secondary school. This could also be accomplished by requiring science courses. Increasing educational performance and providing equal opportunity in disadvantaged schools and communities would increase STEM potentials and add diversity to the STEM employment pool. Establish effective remedial programs, especially in mathematics. Predisposed talent does not determine learning potential. Finally, build suitable adult education programs to popularize science and technology and improve literacy in those domains.

Conclusion

The purpose of this review is to help readers understand the history of STEM instruction and the value of future STEM education reform. This is significant because statistics indicate that United States students have consistently fallen behind on STEM achievement reports compared to other nations. There has been much research on the decline of STEM graduates and the possible detrimental effect on the economy should that trend continue. The importance of STEM education is recognized, but many educators are unsure how to implement the practice. This places the responsibility on school leaders to provide adequate professional development and training to struggling teachers. Without the support of administration, teachers are more likely to become discouraged and revert to a teaching method with which they are comfortable. The reviewed literature indicates a positive connection between STEM methods, project-based learning, real-world connections, and student engagement and achievement. Additionally, research shows at-risk students experience significant benefits from an increase in engagement. Policymakers, state leaders, school administrators, and educators have a responsibility to provide students with the skills necessary to become successful, productive citizens.

CHAPTER 3: METHODOLOGY

Introduction

The purpose of this study was to determine the perceptions of STEM curriculum according to traditional teachers and the effect of STEM teaching methods on student engagement. A qualitative research approach was used to acquire teachers' perceptions of STEM teaching methods and determine the types of methods currently implemented within the classroom. Due to the increasing need for employees in STEM-based jobs, exposure to the STEM disciplines is necessary to prepare students to enter the workforce. The chapter is organized as follows – research questions, specific research approach, description of participants and setting, data collection procedures, ethical considerations, and data analysis procedures.

Research Questions

The following research questions were investigated:

1. By what methods do teachers in a traditional high school setting incorporate STEM teaching methods into their instruction?
2. What are the perceptions of traditional teachers regarding the STEM curriculum?
3. What types of professional development do teachers need to feel comfortable incorporating STEM lessons into their curriculum?

Description of the specific research approach

A qualitative research approach was used for this study to obtain teachers' perceptions of STEM curriculum and to observe techniques currently used within the classroom. Grounded theory was used in the research design. Grounded theory allows the researcher to analyze individual cases and develop more abstract concepts and identify patterns (Charmz & Belgrave, 2007). Information was noted from individual interviews, surveys, and direct classroom observation to observe patterns among the teaching methods used by the participants. The interviews served as the primary source of information, but additional observations were made by the researcher during lessons delivered by the participants. Qualitative research methods were chosen because the most beneficial information for the study was to be collected through interviews and first-hand experiences. The foundation of the study was dependent on the responses of the participants. During the study, the participants provided information concerning best practices for teachers to develop critical thinking skills and increase student interest.

An online survey was used to develop a better understanding of practices that were currently being implemented within the classroom. This allows the researcher to gather data from a larger sample size quicker than individual interviews. After the results of the online survey, teachers were chosen to be interviewed based upon responses to the questions. The survey identified teachers who were knowledgeable of STEM and those who were not. Interviews were conducted with both categories of teachers. The classroom observations allowed the researcher to witness the effects of different teaching strategies on student engagement and provided data necessary to make comparisons.

Description of the Study Participants and Setting

The population for this sample was traditional high school teachers from a rural school district in East Tennessee. The school was a Title I school with over 50% of students receiving free or reduced lunch. The school had a diverse student population with varying socioeconomic backgrounds. This school was chosen because the participants were easily reachable for the researcher. Convenience sampling was used during the study and teacher participation was voluntary. This method is relatively easy and is a common sampling method (Setia, 2016). The study involved an online survey of teachers from the freshman campus of the high school. Six participants from varying disciplines also agreed to let the researcher observe lessons in their classrooms. Students were observed during the study but not directly surveyed.

Data Collection Procedures

Prior to the study, the researcher obtained permission from the Carson-Newman University Institutional Review Board to begin the study and process of data collection. The researcher also followed the protocol of the research district's policy which includes: identification of the researcher as a student of Carson-Newman University; the purpose of the study; research procedures; individuals who will have access to the collected data; what will happen to the data following the study; how confidentiality will be preserved; how risk to subjects will be minimalized; explanation of sampling techniques; instruments to be incorporated into the study; informational documents for participants; and providing participants with a consent form. Once approval was granted by the district, the school administrator allowed the study to begin.

Following approval, an online survey for participants was created using Microsoft Forms. The survey consisted of Likert-scale questions and open-ended responses. The Likert-scale allows participants to answer questions using a range of strongly disagree to strongly agree with a neutral response in the middle (Allen & Seaman, 2007). The questions focused on types of STEM teaching methods already being implemented in classroom based on a checklist of effective STEM integration strategies compiled by the University of Arizona (Arizona Project WET, n.d). The survey aligns with Piaget's Constructivism theory by determining the strategies being used to develop the student's understanding of learning. The open-ended questions allowed the teachers to provide information about their own perceptions of STEM teaching and what additional support was necessary to successfully implement a STEM-focused curriculum.

Secondly, participants were observed for 20-30 minutes during daily lessons. During the observations, the researcher made notes identifying teaching methods used during the lessons and observations of student participation. Thirdly, teachers were interviewed during their planning periods for 30-45 minutes using pre-determined questions that allowed for elaboration. These questions were built from the information gathered from the survey and observations. Grounded theory requires questions that have the possibility to evolve to align with the information needed for the study (Charmaz & Belgrave, 2007). The interviews were recorded and then transcribed. The questioning provided a deeper understanding of the teachers' perceptions of STEM and permitted teachers to express opinions concerning the implementation of a STEM curriculum.

Ethical Considerations

Prior to the beginning of the study, the research proposal and survey were submitted to the principal of the school who sent district-required information to the appropriate district-level supervisor for approval. Participation in the study was completely voluntary. Therefore, a consent form was provided to each participant to inform him/her of the purpose of the study. The consent form also highlighted the option of non-participation. Participants were not required to provide any type of identifying information.

Data Analysis Procedures

The online questionnaire administered to 30 teachers at the research school was a Likert-type survey. Open-ended questions were located at the end of the survey to allow participants to provide feedback and extensive answers to questions. Surveys were analyzed and answers were grouped to determine overall teacher perception of STEM teaching methods. Participants were selected to interview after the survey was completed based on prior knowledge of STEM teaching methods. To have an adequate representation, an educator from five disciplines (science, mathematics, English language arts, history, and visual arts) was selected to participate in an interview. Interviews consisted of open-ended questions which allowed for elaboration to acquire a deeper understanding of teacher views. After the interviews, data analysis occurred. The audio recordings and notes gathered from the interviews were transcribed. The transcripts were available to the participants for accuracy verification. Classroom observations were conducted within the six interview participants' classrooms. The observed lessons were recorded to be reviewed thoroughly. Notes related to types of teaching methods used in the classroom were composed during the observations. Throughout the entire process, findings were discussed with a peer debriefer. The role of the peer debriefer was to reduce bias by challenging the researcher to only use themes and conclusions wholly supported by data. Member checks were conducted to verify accuracy and validity of the findings the analysis yielded. The member checks also provided data for clarification of the findings.

Data analysis began during the observations using a checklist that described characteristics of effective STEM integration. Following the observations, patterns and themes were identified from the transcriptions that were related to the research questions. To effectively analyze qualitative data, a systematic process must be used to organize responses and discover commonalities (Vaughn & Turner, 2016). Data were obtained via survey, interviews, and observations and coding analysis was performed throughout the study as data became available. Coding is defined as the research process that involves annotating, describing, and linking different portions of the data collected from the participants.

Open coding was used during the interviews and observations by writing notes and headings in the transcriptions. The notes were then used to generate categories and observe patterns. The patterns were determined by highlighting similar words and concepts within the responses of the participants. The list of categories was then grouped into higher order categories, combining those of similarity. Following open coding, axial coding was used to further compare the patterns and determine relationships within the codes. Selective coding was then used to combine categories and themes to develop a more complete understanding of the research. After the completion of coding, peer debriefing was used. To eliminate bias and ensure validity, a peer debriefer was involved throughout the study to prompt deeper analysis of findings and to question data inferences. Peer debriefing is defined as the process of exposing the methods and results of a study to a disinterested peer in a manner that resembles an analytic session to acquire a different perspective and receive support (Barber & Walczak, 2009). Member checks were also conducted to verify that participant interview transcripts were accurate. Member checking, also known as participant or respondent validation, is a technique used to insure the credibility of data. Data or results are returned to participants to verify the accuracy of their experiences (Birt et al., 2016).

Summary

The qualitative research design method was used in this study to utilize a natural setting and allow the participants to determine the direction of the research. The observations and semi-structured interviews were recorded and then transcribed. The data were then coded and studied to determine connections and themes. The information from this study will be useful in creating STEM training professional development sessions and improving the application of STEM teaching methods in the classroom.

CHAPTER 4: PRESENTATION OF FINDINGS

The purpose of this qualitative study was to identify secondary teachers' perceptions of integrated STEM education. This study was based on three types of data to support triangulation. Data related to teaching methods and teacher perceptions were collected via an online teacher questionnaire, classroom observations, and semi-structured interviews. Member checks and peer debriefing were used to maintain credibility and ensure the validity of the study. Data gathered were analyzed to investigate the following research questions:

1. By what methods do teachers in a traditional high school setting incorporate STEM teaching methods into their instruction?
2. What are the perceptions of traditional teachers regarding the STEM curriculum?
3. What types of professional development do teachers need to feel comfortable incorporating STEM lessons into their curriculum?

The data analysis procedures and the results of the study are discussed in this chapter.

Selection of Participants

For this study, a convenience sample was selected from a secondary school in East Tennessee. A voluntary online questionnaire using Microsoft Forms was sent by email to all teachers at a freshmen campus. Purposeful sampling was used to select interview participants from the responses.

Summary of Questionnaire Prompts and Responses

The response to the online survey from teachers asked to participate consisted of 20 of 30, or a 67% return rate. Each respondent answered demographic questions and 14 different prompts regarding teaching methods. The demographic questions consisted of subject taught and years of experience. The responses varied among eight different subject areas taught and four different ranges of experience. The eight different subject areas taught represented in the survey were English Language Arts, Algebra I, Biology I, World History, Visual Arts I, business, agriculture, and special education. Teaching subject-area instructor totals included six English language arts, four Algebra I, three Biology I, one agriculture, one business, three World History, one special education, and one visual arts. There were 20 total responses for subject area taught. Table 4.1 represents the total number of subject areas taught by survey participants.

Table 4.1
Subject Areas Taught by Questionnaire Participants and Percentage of Sample

Subject Area Taught	**Number of Participants**	**% of Participants**
English Language Arts	6	30
Mathematics	4	20
Science	3	15
World History	3	15
Business	1	5
Agriculture	1	5
Visual Arts	1	5
Special Education	1	5
Total	**20**	**100%**

The years of experience question for educator respondents was grouped into four categories and resulted in four teachers in the 0-5 years of experience category, 11 teachers in the 6-15 years of experience category, two teachers in the 16-25 years of experience category, and three teachers in the more than 25 years of experience category. Table 4.2 represents the total number of years of experience of the survey participants.

Table 4.2

Years of Experience of Questionnaire Participants

Years of Experience	Number of Participants	% of Participants
0-5	4	20
6-15	11	55
16-25	2	10
26+	3	15
Totals (N=20)		

The 14 prompts asked participants about teaching methods used within the classroom and participants indicated their agreement on a five-point Likert scale. The prompts consisted of verified STEM teaching methods acquired from a list created by the University of Arizona. Following the Likert-style questions were two open-ended questions to develop a deeper understanding of the perceptions of teachers regarding the implementation of STEM in the classroom.

Prompt 1. *A variety of technologies is used in my classroom.*

Of the 20 participants who responded to the survey, a higher percentage agreed that a variety of technologies was used in their classrooms compared to those who disagreed. The research school is a 1:1 school where each student receives a personal laptop. Choice (4) *Agree* was selected by 65% of teachers and (5) *Strongly Agree* was selected by 10% of teachers. Next, 25% of respondents chose (3) *Neither Agree nor Disagree.* Table 4.3 displays the data gathered from Prompt 1.

Table 4.3

Prompt 1. A Variety of Technologies is Used in my Classroom.

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	0	0
(3) Neither Agree nor Disagree	5	65
(4) Agree	13	10
(5) Strongly Agree	2	25
Totals (N=20)		

Prompt 2. *During class students work on technology-enhanced projects that approach real-world applications of technology.*

When asked to respond to the type of projects used in class, there were zero responses to (1) *Strongly Disagree.* Choice (2) *Disagree* was selected by 15% of participants. Choice (3) *Neither Agree nor Disagree* was selected by 20% of participants and 5% chose (5) *Strongly Agree.* The highest number of participants, 60%, chose (4) *Agree.* Table 4.4 illustrates the data gathered from Prompt 2.

Table 4.4

Prompt 2. During Class Students Work on Technology-enhanced Projects That Approach Real-world Applications of Technology.

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	1	15
(3) Neither Agree nor Disagree	4	20
(4) Agree	12	60
(5) Strongly Agree	1	5
Totals (N=20)		

Prompt 3. *During class students use technology to help solve problems.*

In the same manner, 75% of participants stated that they (4) *Agreed* that students participated in problem-solving scenarios involving technology. Furthermore, 15% selected (5) *Strongly Agree.* Conversely, 10% displayed a neutral stance and selected (3) *Neither Agree nor*

Disagree. No participants disagreed with Prompt 3. Table 4.5 displays the data gathered from Prompt 3.

Table 4.5
Prompt 3. During Class my Students use Technology to Help Solve Problems.

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	0	0
(3) Neither Agree nor Disagree	2	10
(4) Agree	15	75
(5) Strongly Agree	3	15
Totals (N=20)		

Prompt 4. *During class students develop problem-solving skills through investigations or inquiry.*

No participants stated that they disagreed when asked if students used investigations or inquiries to solve problems. (4) *Agree* was the most selected choice having been chosen by 60% of participants. (5) *Strongly Agree* and (3) *Neither Agree nor Disagree* were each selected by 20% of teachers. Table 4.6 illustrates the data gathered from Prompt 4.

Table 4.6
Prompt 4. During Class Students Develop Problem-solving Skills Through Investigations or Inquiry.

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	0	0
(3) Neither Agree nor Disagree	4	20
(4) Agree	12	60
(5) Strongly Agree	4	20
Totals (N=20)		

Prompt 5. *During class students work in small groups.*

When asked if students participated in small group work, participants indicated that they overwhelmingly agreed. This was evidenced by 65% of teachers selecting (5) *Strongly Agree* and 25% selecting (4) *Agree.* No participants chose (1) *Strongly Disagree* or (2) *Disagree*, but *10%* expressed neutrality by choosing (3) *Neither Agree or Disagree.* Table 4.7 displays the data gathered from Prompt 5.

Table 4.7
Prompt 5. During Class Students Work in Small Groups

Likert Score	**Number of Participants**	**% of Participants**
(1) Strongly Disagree	0	0
(2) Disagree	0	0
(3) Neither Agree nor Disagree	2	10
(4) Agree	5	25
(5) Strongly Agree	13	65
Totals (N=20)		

Prompt 6. *Students make predictions that can be tested.*

In like manner, educators were asked if students created testable predictions. Participants generally (4) *Agreed* that predictions were created, as evidenced by the 55% of teachers selecting the option. However, 15% of educators, all of which teach English and history, chose (1) *Strongly Disagree.* The remaining 25% of participants chose (3) *Neither Agree nor Disagree*. Table 4.8 illustrates the findings gathered from Prompt 6.

Table 4.8
Prompt 6. Students Make Predictions that can be Tested.

Likert Score	**Number of Participants**	**% of Participants**
(1) Strongly Disagree	3	15
(2) Disagree	0	0
(3) Neither Agree nor Disagree	5	25
(4) Agree	11	55
(5) Strongly Agree	0	0
Totals (N=20)		

Prompt 7. *Students use tools to gather data, e.g. calculators, computers, software, scales, rulers, etc.*

Next, participants were asked to indicate whether data gathering tools were used during class. Of the responses, 40% of teachers chose (5) *Strongly Agree* and 30% chose (4) *Agree*. Conversely, 10% from English and visual arts chose (1) *Strongly Disagree*. The remaining 15% chose (3) *Neither Agree nor Disagree.* Table 4.9 displays the data gathered from Prompt 7.

Table 4.9
Prompt 7. Students use Tools to Gather Data.

Likert Score	**Number of Participants**	**% of Participants**
(1) Strongly Disagree	2	10
(2) Disagree	0	0
(3) Neither Agree nor Disagree	4	20
(4) Agree	6	30
(5) Strongly Agree	8	40
Totals (N=20)		

Prompt 8. *Students record, write, or diagram information using their own formats, such as in journals or notebooks.*

To further investigate data collection, participants were asked if students document information. Of the 20 participants, 40% chose (5) *Strongly Agree* and 20% chose (4) *Agree.* The remaining 40% chose (3) *Neither Agree or Disagree*, but no respondent answered (2) *Disagree* or (1) *Strongly Disagree.* The data gathered from this prompt is illustrated in Table 4.10.

Table 4.10
Prompt 8. Students Record, Write, or Diagram Information Using Their Own Formats.

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	0	0
(3) Neither Agree nor Disagree	8	40
(4) Agree	4	20
(5) Strongly Agree	8	40
Totals (N=20)		

Prompt 9. *Students engage in content-driven dialogue.*

Participants were then asked about the use of content-driven dialogue in the classroom. There was an overwhelmingly positive response with 60% selecting (5) *Strongly Agree* and 30% selecting (4) *Agree.* Additionally, 10% of educators from business and mathematics answered neutrally but did not disagree. Results gathered from the respondents are displayed in Table 4.11.

Table 4.11
Prompt 9. Students Engage in Content-driven Dialogue

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	0	0
(3) Neither Agree nor Disagree	2	10
(4) Agree	6	30
(5) Strongly Agree	12	60
Totals (N=20)		

Prompt 10. *Students share their work publicly to enhance learning for their peers.*

When asked how often students share results, participant responses were more negative than any previous prompt. 55% of educators selected (2) *Disagree* and 10% selected (1) *Strongly Disagree.* The 20% of respondents who answered (5) *Strongly Agree* belong to art, history, and

English, which are not STEM-disciplines. The remaining 15% answered (4) *Agree* and belong to the non-STEM disciplines of history and agriculture. The data gathered from Prompt 10 is displayed in Table 4.12.

Table 4.12
Prompt 10. Students Share Their Work Publicly to Enhance Learning for Their Peers

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	2	10
(2) Disagree	11	55
(3) Neither Agree nor Disagree	0	0
(4) Agree	3	15
(5) Strongly Agree	4	20
Totals (N=20)		

Prompt 11. *Students learn about STEM careers or careers related to your own content.*

Next, participants were asked if students were exposed to potential STEM careers or careers related specifically to their content. Educators almost unanimously disagreed with 50% selecting (1) *Strongly Disagree* and 45% selecting (2) *Disagree*. The 5% who answered (4) *Agree* taught agriculture. The data gathered from Prompt 11 is organized in Table 4.13.

Table 4.13
Prompt 11. Students Learn About STEM Careers or Careers Related to Your Own Content

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	10	50
(2) Disagree	9	45
(3) Neither Agree nor Disagree	0	0
(4) Agree	1	5
(5) Strongly Agree	0	0
Totals (N=20)		

Prompt 12. *I know about current STEM careers.*

Prompt 12 asked teachers to describe their own knowledge of STEM careers. The majority of responses indicated that teachers are unsure of information regarding choices of STEM careers. This was evidenced by 30% of participants selecting (3) *Neither Agree nor Disagree* and 25% selecting (2) *Disagree.* Those who felt confident of their knowledge of STEM careers consisted of all teachers surveyed who taught a STEM discipline or vocational course. This was represented by 40% selecting (4) *Agree* and 5% selecting (5) *Strongly Agree.* Data gathered from Prompt 12 is displayed in Table 4.14.

Table 4.14
Prompt 12. I Know About STEM Careers

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	5	25
(3) Neither Agree nor Disagree	6	30
(4) Agree	8	40
(5) Strongly Agree	1	5
Totals (N=20)		

Prompt 13. *I know where to find resources to teach students about STEM.*

Participants were confident in their abilities to locate STEM resources if necessary. This is supported by 55% of respondents choosing (4) *Agree* and 10% choosing (5) *Strongly Agree.* The 30% of participants who chose (2) *Disagree* and the 10% who chose (3) *Neither Disagree nor Agree* were teachers of non-STEM disciplines. The data related to Prompt 13 is illustrated in Table 4.15.

Table 4.15

Prompt 13. I Know Where to Find Resources to Teach Students About STEM.

Likert Score	Number of Participants	% of Participants
(1) Strongly Disagree	0	0
(2) Disagree	6	30
(3) Neither Agree nor Disagree	1	5
(4) Agree	11	55
(5) Strongly Agree	2	10
Totals (N=20)		

Prompt 14. *I know what teaching methods are STEM methods.*

When asked about personal knowledge of STEM methods, several responses indicated an uncertainty of what qualifies as STEM teaching. A divide between disciplines could be observed from the result. All participants who taught English expressed doubt and chose (2) *Disagree* or (3) *Neither Agree nor Disagree.* The majority of responses had negative implications with 30% of participants choosing (2) *Disagree* and 25% choosing (3) *Neither Agree nor Disagree.* Conversely, 35% chose (4) *Agree* and 10% chose (5) *Strongly Agree.* These choices were selected primarily by teachers of STEM disciplines. The results for Prompt 14 are displayed in Table 4.16.

Table 4.16

Prompt 14. I Know What Teaching Methods are STEM Methods.

Likert Score	**Number of Participants**	**% of Participants**
(1) Strongly Disagree	0	0
(2) Disagree	6	30
(3) Neither Agree nor Disagree	5	25
(4) Agree	7	35
(5) Strongly Agree	2	10
Totals (N=20)		

Questionnaire Open-Ended Question One

The first open-ended question was, "What are your thoughts about implementing STEM in your classroom?" Of the 20 participants who submitted the online questionnaire, 19 answered the first open-ended question. After the analysis of data, several themes emerged in relation to the question. A common response was concern regarding the lack of time to incorporate project-based learning into the curriculum. Participant 1, a mathematics teacher, responded "I would love to but struggle due to time constraints." Teachers already struggle with the delivery of required state standards and the review period before state testing begins. Participant 4, also a mathematics teacher, echoed the concern for lack of time by stating "The vast majority of STEM lesson plans I've seen involved project-based learning. I adore project-based learning, but I have difficulty with the amount of time involved in implementing a rigorous project to hit both math and science standards." Teacher responses indicated awareness of the need for STEM in the classroom but expressed uncertainty in their ability to incorporate STEM. Participant 15, an English teacher, responded "As an English teacher, I feel incompetent trying out STEM activities since my own background in those areas is not very developed. However, with a little training, I think I would be more aware of opportunities to integrate STEM into activities I already teach but just need to extend to include more STEM." In addition to the need for training, some teachers wanted access to content-specific resources to aid in implementation. Participant 7, a mathematics teacher, was already knowledgeable of STEM but needed additional support. She said, "I like to incorporate STEM. I just need more resources that are related to my curriculum." Another common response was the supposition that STEM teaching only applies to those who teach STEM disciplines. Participant 8, a history teacher, said "From what I've read, STEM involves primarily math and science. However, there are times when cooperative problem solving can apply to any subject." Additionally, several teachers acknowledged their lack of knowledge of how to incorporate STEM but expressed their willingness to attempt anything that would benefit their students. Participant 9, an English teacher, stated "I am not knowledgeable of STEM, but I am open to implementing strategies into my classroom." Overall, the responses to the first open-ended question indicated that educators are open to experimenting with integrating STEM into their curriculum. Participant 10, an English teacher, acknowledged not only the importance of STEM skills in schools but the need for those skills as adults. He responded, "I think it is important. The skills students learn from integrating STEM in my classroom are basic expectations in the post-secondary world no matter what pathway a student chooses." The key findings of open-ended question one are detailed in Table 4.17.

Table 4.17

Key Findings of Open-Ended Question One

Key Findings	**Number of Participants**	**% of Participants**
Lack of time	3	15
Not confident in ability	3	15
Open to trying	3	15
Difficult	3	15
It is important	3	15
Applies to math and science	2	10
Unsure	2	10
Need more resources	1	5
Totals (N=20)		

Open-Ended Question Two

Open-ended question two asked teachers to describe the type of support they would like or need to achieve their own goals for STEM teaching and learning. Of the 20 questionnaire participants, 19 provided an answer to this question. This provided information necessary to support teachers through professional development. The most requested support involved content-specific resources and how to make STEM relevant to non-STEM disciplines.

Participant 11, a special education teacher, requested “collaborative learning groups where I could learn a technique applicable to my current class/students and get feedback in the process of implementing that technique; a place where I could ask questions and learn from others implementing that same technique.” Also, resources such as books, templates, and mentors were suggested. The lack of time concern reappeared in the responses to this question as well. Participant 13, a science teacher, said to successfully incorporate STEM, he would need “less demands on state level content requirements and more time to innovate teaching to actual investigation and experimentation.” Several teachers said that they would require basic training to overcome their lack of knowledge before they could set goals. Participant 18, a visual arts teacher, responded “Overcoming my own lack of comfort using technology is a challenge. Organizing student integrated projects is too time consuming at the present. I need to figure out how to allow students to collaborate and still be individually accountable.” Some participants had no goals established for incorporating STEM and instead would like to focus solely on their curriculum. Participant 12, an English teacher, stated “I do not currently have any goals as associated with STEM. I typically focus on how students who are not connected with English curriculum could use my curriculum in careers (including those associated with STEM).” The key findings of open-ended question two are illustrated in Table 4.18.

Table 4.18
Key Findings of Open-Ended Question Two

Key Findings	**Number of Participants**	**% of Participants**
Content-specific resources	5	26
Collaboration	4	21
Content-area training	4	21
Explain relevancy	3	16
More time	3	16
Totals (N=20)		

Interviews

After all responses were recorded from the questionnaire, participants were selected to be interviewed to gain a deeper understanding of teacher perception. Selection was based upon knowledge and interest in STEM integration with all levels being represented. The teachers were asked to consider their own knowledge of STEM and how the methods are integrated in their classrooms. All teachers were asked the same leading questions in a semi-structured interview. Member checks were conducted to confirm accuracy of the responses and to correct any misunderstandings. Each session was recorded and then transcribed for each participant. The questions were developed to include knowledge of STEM, implementation of STEM, perception of integration of STEM, and professional development needed to increase confidence of ability to incorporate additional methods. The questions for the interviews included:

1. What do you think of when you hear STEM education?
2. What do you think qualifies as STEM teaching methods?
3. How comfortable do you feel about incorporating STEM into your lessons?
4. What additional training do you need to be successful?

The responses were analyzed for themes using open coding across each interview to determine the teachers' perceptions and current level of STEM implementation. Responses were analyzed for each participant and compared to the responses gathered from the initial questionnaire that determined the overall perception of STEM education. In addition to the responses, classroom observations of each interview participant were conducted to identify current STEM teaching methods already being implemented. This ensured accuracy of responses through triangulation and provided evidence used to determine knowledge of STEM education.

Interview Data

The semi-structured interviews provided a deeper understanding of secondary teachers' perceptions of integrated STEM education. The interview process consisted of six interview sessions composed of four open-ended leading questions. A journal and audio recordings were used to guarantee that all responses were recorded and interpreted with accuracy. The interviews varied from 20 minutes to 45 minutes. To ensure reliability of the data collection process, peer debriefing was used after the interview data had been coded and transcribed. An unbiased peer debriefer not involved in the study reviewed the methods and reported data and determined the research as valid and credible. Member checks permitted the participants to review the transcriptions to ensure that the responses were interpreted correctly. Interviews were the primary source of data, but triangulation was attained by also examining questionnaire responses and classroom observations. All six interview sessions took place on January 11, 2019. The six teachers interviewed for this study taught various disciplines at the secondary level. The sampling selection began with the initial questionnaire emailed to all teachers at the research school. Teachers were informed of the study and provided an informed consent document. The teachers could respond on the questionnaire if they were willing to be interviewed and observed. The number of participants was minimized using purposeful sampling. Selection was based on representation of a variety of subject areas taught, years of experience, and primary knowledge of STEM education. The interviewees consisted of a Caucasian female who has taught science for 16 years, Caucasian female who has taught English for 11 years, Caucasian male who has taught history for 33 years, Caucasian female who has taught English for 7 years, Caucasian female who has taught math for 9 years, and a Caucasian male who has taught visual arts for 22 years. All participants currently teach at the 9th grade level. Table 4.19 illustrates the subject area taught and years of experience for each interview participant.

Table 4.19
Subject Taught and Years of Experience of Interview Participants

Participant	Subject Area Taught	Years of Experience
Participant 1	Biology	16
Participant 2	English	11
Participant 3	History	33
Participant 4	English	7
Participant 5	Mathematics	9
Participant 6	Visual Arts	22

Study Findings

The interviews were conducted individually with six teachers in a variety of disciplines. All interviews occurred in a school setting after the interview questions were reviewed for possible misconceptions by a secondary administrator who did not participate in the study. From the interviews, four themes emerged concerning the implementation of STEM in the classroom; time constraints, the need for professional development, relevance to subject, and lack of confidence and ability to integrate STEM due to lack of knowledge of the topic.

Time Constraints due to Standardized Testing

The most common concern among participants was the lack of time available to complete STEM projects. Project-based learning is an important component of successful STEM implementation and can take extensive class time to complete. With the pressures of state standardized testing and teacher accountability, teachers were concerned about losing valuable time needed to prepare for the test. During the interview, Participant 5 said “Until we have something other than end of course testing, nothing is going to change about our training methods. I spend way more time delivering the content than actually using it. I don’t have time.”

Participant 1 echoed this concern by stating, “I enjoy STEM projects, but I simply do not have the time to incorporate them beyond enrichment. I have so many standards to cover and cannot risk losing the time I need to get through everything.” Participant 4 was also concerned about losing valuable class time but more concerned about the time it would take for her to learn a different style of teaching. She said, “I am open to trying anything that will help my students, but I am worried that it will take so much time for me to learn about STEM since my knowledge of it is very basic.”

Professional Development

When asked about professional development, all interview participants unanimously agreed that restructuring was essential if integrated STEM education were to ever be a focus. All six educators identified their specific needs for professional development. Participant 1, a science teacher, expressed frustration with the lack of time available to collaborate with teachers who have similarly structured classes. The classes she teaches are year-long compared to the standard block schedule. She said, “I want to sit down with teachers who teach the same classes as me for the same length of time. Let’s research things and share ideas and see what works and what doesn’t.”

Participant 2, an English teacher, stated that she preferred professional development that she could take something concrete from to refer to as a reference. Although she has experienced some brief STEM training, she stated, “I would like to have a written article defining exactly what is STEM. Give me a list or a template. I need something to follow.”

Participant 3, a history teacher, described his preference for independent professional development. During his 33 years in education, he has experienced various methods of exposure to new teaching strategies. He stated, “I would like to see some good videos of teachers implementing STEM. I want to see it done and not be told how to do it.”

Participant 4, an English teacher, was concerned about her lack of knowledge of STEM. She felt that differentiated training would benefit her the most. She said, “If I could see examples of things I could do in an English class, it would help me. My STEM knowledge is basic at best, but I am open to trying new things if it will benefit my students.”

Participant 5, a mathematics teacher, said that she needed extensive training because of her lack of knowledge. She said, “I need the basics because I only know what it stands for. There should be general training and then split by subject matter with a STEM professional. Go from everybody to just math to just Algebra I. I need to know what should be happening in my subject. Direct instruction would be the most beneficial.”

Participant 6, a visual arts teacher, expressed frustration with the lack of content-based training available. He described his technology skills as basic with the need of extensive training. He said, “I would need individualized help. The lab training we get is pointless for me. One, I’m distracted and two, it doesn’t really apply to my world. If I ask questions that do apply, I feel that the rest of the room becomes resentful. I need content-based instruction. I look for training on my own to try to figure things out.”

Content Relevance

Several teachers of non-STEM disciplines reacted in the same manner when asked their opinions of implementing STEM in the classroom. They questioned STEM’s relativity to their classes. Participant 2, an English teacher, expressed how difficult it is to implement STEM in a non-STEM discipline even after receiving training. She said, “Technology is easy to implement in English, especially since we have laptops now. It’s hard to implement STEM because we don't have that aspect of study with English. There are no experiments and answers are not always objective. Technology is the easiest, but the rest is tough. Certain subjects lend themselves better than others. You have to think outside the box to incorporate in non-STEM subjects. It's not how we were taught or how we learned in college. The technology is not difficult but as far as teaching, you can incorporate anything in anything if you try. I use problem- solving and student led activities. I don't feel like STEM schools do anything differently. They just have that stigma. We used to have problem-solving standards but now they are built in to all the standards. It's easier to teach with more student-led lessons. Math works for poetry when I teach meter. The science part is probably the most difficult for me to include." Participant 3 also indicated that STEM was difficult to apply in a history class. He said, "From what I have read, STEM is related more to math and science. However, there are time when cooperative learning can apply to any subject."

Lack of Confidence

Most participants, even those teaching STEM disciplines, acknowledged their lack of comfort when trying to implement new strategies in the classroom. This was largely due to the lack of knowledge regarding STEM integration. Several participants said that they knew very little about STEM education beyond the four disciplines included in the acronym. Some could name popular STEM methods such as projects, research, and real-world connections. Participant 5 said, "I do not feel comfortable. I know what it is roughly, but I've never really thought about how I should put it in my classroom." Participant 4 displayed uncertainty when asked about her comfort level. She described her STEM knowledge as basic and in need of extensive training. She explained, "I have no idea how to apply it to English. I really don't know what it is besides what it stands for."

Teacher Classroom Observations

For the observation portion of data collection, the same six teachers who were interviewed were also observed for 20 minutes of a 90-minute class period. The observations provided detailed information of the types of teaching methods currently being implemented within the classroom. The researcher recorded the lesson and made notes in a journal. A checklist of effective STEM teaching methods compiled by the University of Arizona was used to determine the application of such methods.

Participant 1, a science teacher, indicated on the survey that she was confident in her knowledge of STEM but was only able to implement projects for enrichment. While observing her class, several STEM methods were witnessed. The students were working in pairs to complete a project. Student collaboration is an effective STEM measure that promotes teamwork. While working together, the students were researching different types of headphones as well as a range of prices. Once the data on price points was gathered, the students had to find the mean, median, and mode for the data set. This incorporated math into the project. Students were to then design their own model of headphones and present the findings on a poster. This lesson involved all four of the STEM disciplines. The students were engaged in the project and eager to present their creations.

Participant 2, an English teacher, disclosed in an interview that she was confident in the disciplines of STEM but not in her ability to incorporate them into her curriculum. During the observed lesson, students were presented with the lyrics to the song “American Pie” to reference as they listened. Following the song, the students were introduced to the inspiration for the song, Buddy Holly, through a news broadcast. Students were sitting in groups of three and proceeded to work together to research the song lyrics, looking for any references to Buddy Holly hidden in the song. Several STEM methods were documented during this lesson. Students were collaborating while using technology to research a song that pertained to real-world events. Students shared their findings through whole-class discussion.

Participant 3, a history teacher, expressed his confidence in STEM delivery in an honors classroom setting but indicated that the majority of his standard-level students did not possess the maturity to participate in a STEM project. During the observation, the teacher began by presenting information about appeasement and its role in World War II. Students took notes for 10 minutes. The teacher then introduced the activity by distributing primary sources to each group. Students were working together in groups to analyze primary sources while answering questions provided on a worksheet. After seven minutes, the students rotated to the next station to analyze the next primary source. This continued until all questions were answered. At the conclusion of the period, the class discussed opinions concerning the appropriateness of appeasement. The STEM methods observed during the class consisted of student-to-student collaboration, real-world connections through text, presentation of findings through discussion, and the requirement of students to reflect and revise.

Participant 4, an English teacher, stated during the interview that she had no knowledge of STEM except for what the acronym represented. The lesson selected to be observed was during the teacher’s inclusion period. The teacher began with a warm-up question reviewing the concept addressed in a previous lesson. The next task involved a class discussion where students shared their thoughts about a poem they each had read. Every 10 minutes, the teacher would pause and do a “candy challenge” that involved a real-world related trivia question. The student who answered correctly would receive a piece of candy. These questions kept students engaged throughout the lesson by breaking the discussion into smaller parts. The STEM methods observed during this lesson include student-to-student collaboration through discussion, real-world connections using trivia questions, presentation of student findings through communication, and criteria-based assessment from the teacher.

Participant 5, a mathematics teacher, said that she was not comfortable with the implementation of STEM and had never really thought about what methods might be considered STEM methods. The observed lesson began with the review of a previous lesson about compound interest. Students continued working on an assignment from the day before. They completed the assignment individually and then approached the teacher's desk to have their answers assessed. STEM methods observed during this lesson include the solving of real-world problems using interest and criteria-based assessment from the teacher.

Participant 6, a visual arts teacher, revealed during the interview that he was comfortable with some aspects of STEM but struggled with newly developed technology. During the observation of the class, students were working in teams while using laptops to research information and images while creating a PowerPoint presentation. STEM methods that were evident in this lesson included student collaboration, student communication and presentation of findings, requiring students to reflect and revise, and criteria-based assessment from students themselves and the teacher. With this being an art class, methods specific to this discipline would be categorized into the STEAM methods category.

Summary of Observation Data

The six teachers chosen to be observed had a variety of perspectives of what it means to incorporate STEM education. On the initial survey, two of the observed teachers indicated that they were confident in their knowledge of STEM teaching methods and were comfortable using them in the classroom. The remaining four teachers expressed doubt in their abilities to incorporate them efficiently. During the observations, the two teachers who were confident in their abilities were successfully using some approved methods. One teacher was completing a STEM-specific project and incorporating all four disciplines. The second was incorporating real-world primary source documents, small groups, and the sharing of thoughts during a class discussion. The four observed teachers who expressed a lack of STEM knowledge were using several STEM methods in their lessons but were unaware. The most common method used was students working in small groups and sharing ideas. During the interviews, the teachers said that this is a strategy that they commonly use but they did not know that it was an approved STEM method. The teachers knew the importance of students learning from each other and incorporated this method almost daily. All six of the observed teachers identified the necessity of relating lessons to students using real-world connections. Three of them used this method to keep students engaged, not knowing they were using STEM methods. The remaining three knew that this particular method was considered STEM, but they also acknowledged that it was a crucial part of keeping students interested in the lesson. In summary, all six observed teachers were incorporating STEM methods into their daily lessons. Only one teacher was implementing a true STEM project that incorporated the four disciplines into one lesson. The remaining five teachers used a variety of STEM methods distributed over several days of lessons.

Study Findings

After completing the initial stage of data collection, the data were organized using open, axial, and selective coding. Using the data, categories were constructed to provide an understanding of secondary teachers' perceptions of integrated STEM curriculum and what methods were currently being implemented in the classroom. During the open and axial coding processes, themes were established to support categories used to provide evidence for answers to the research questions. Selective coding was used to separate the data into three categories that provide answers to the three research questions. Tables 4.20, 4.21, and 4.22 illustrate the coding used for the study.

Table 4.20

Data Sorted in Levels of Coding for Research Question One: By what methods do teachers in a traditional high school setting incorporate STEM teaching methods into their instruction?

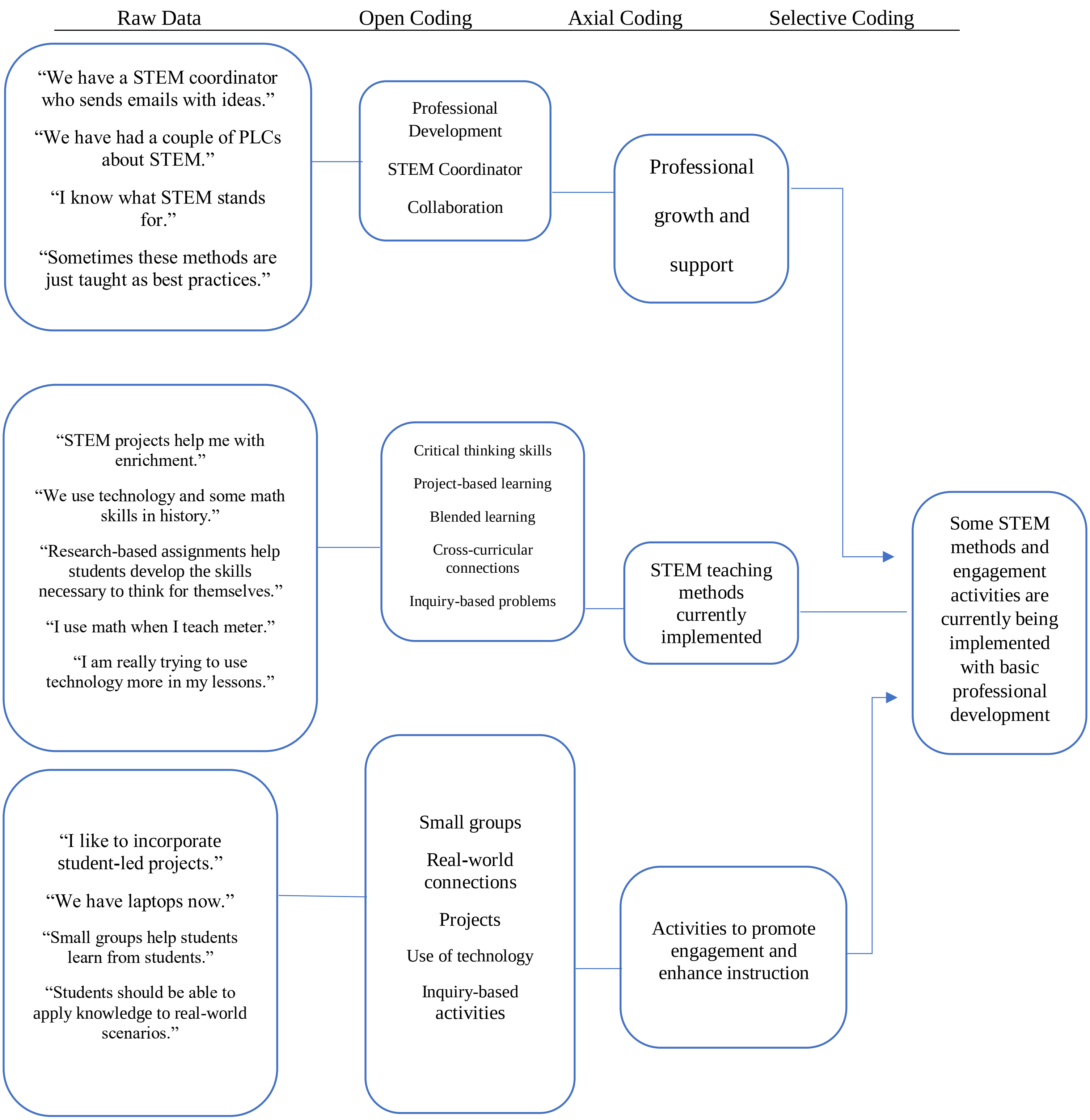


Table 4.21

Data Sorted in Levels of Coding for Research Question Two: What are the perceptions of traditional education teachers regarding STEM curriculum?

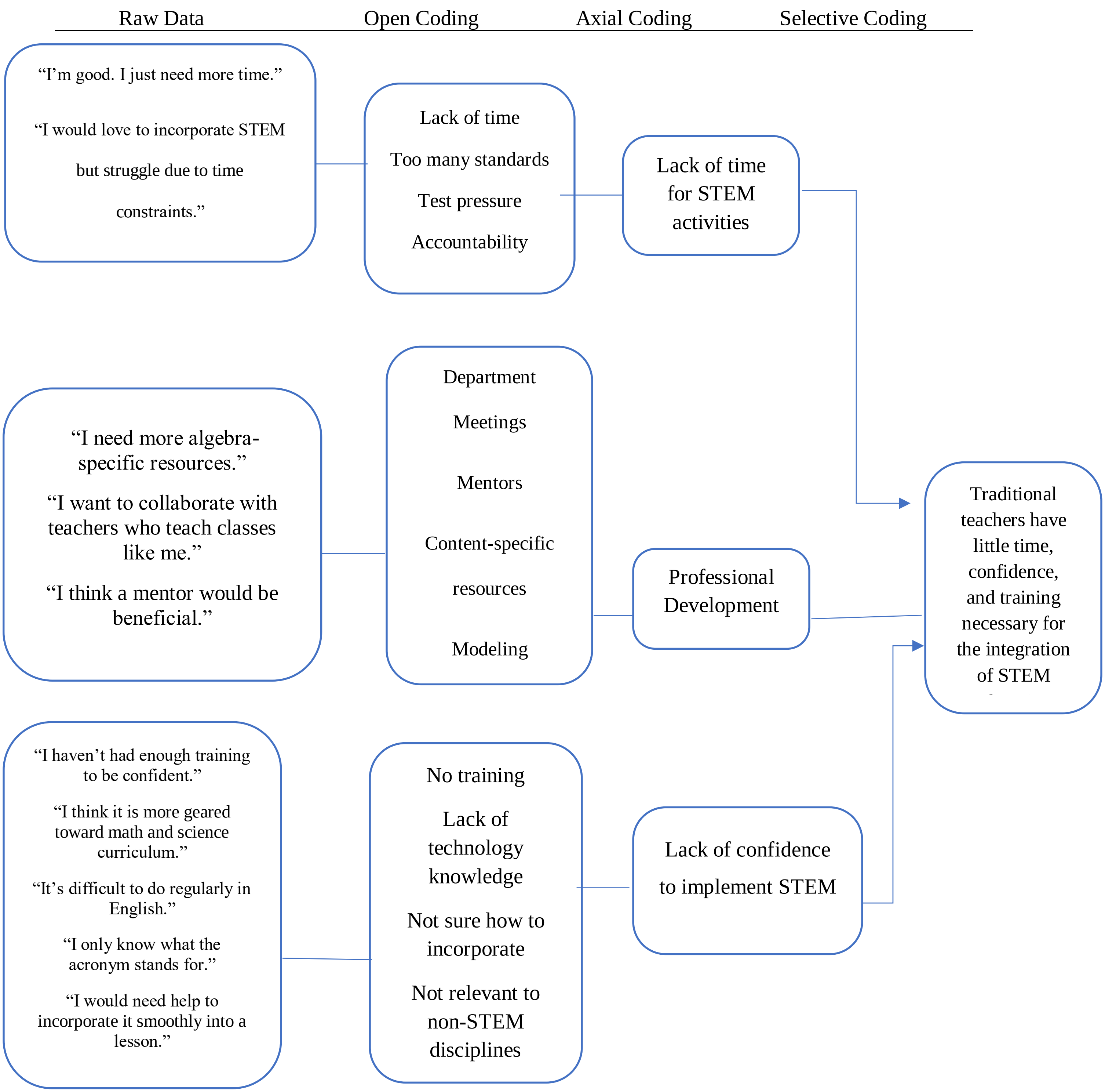
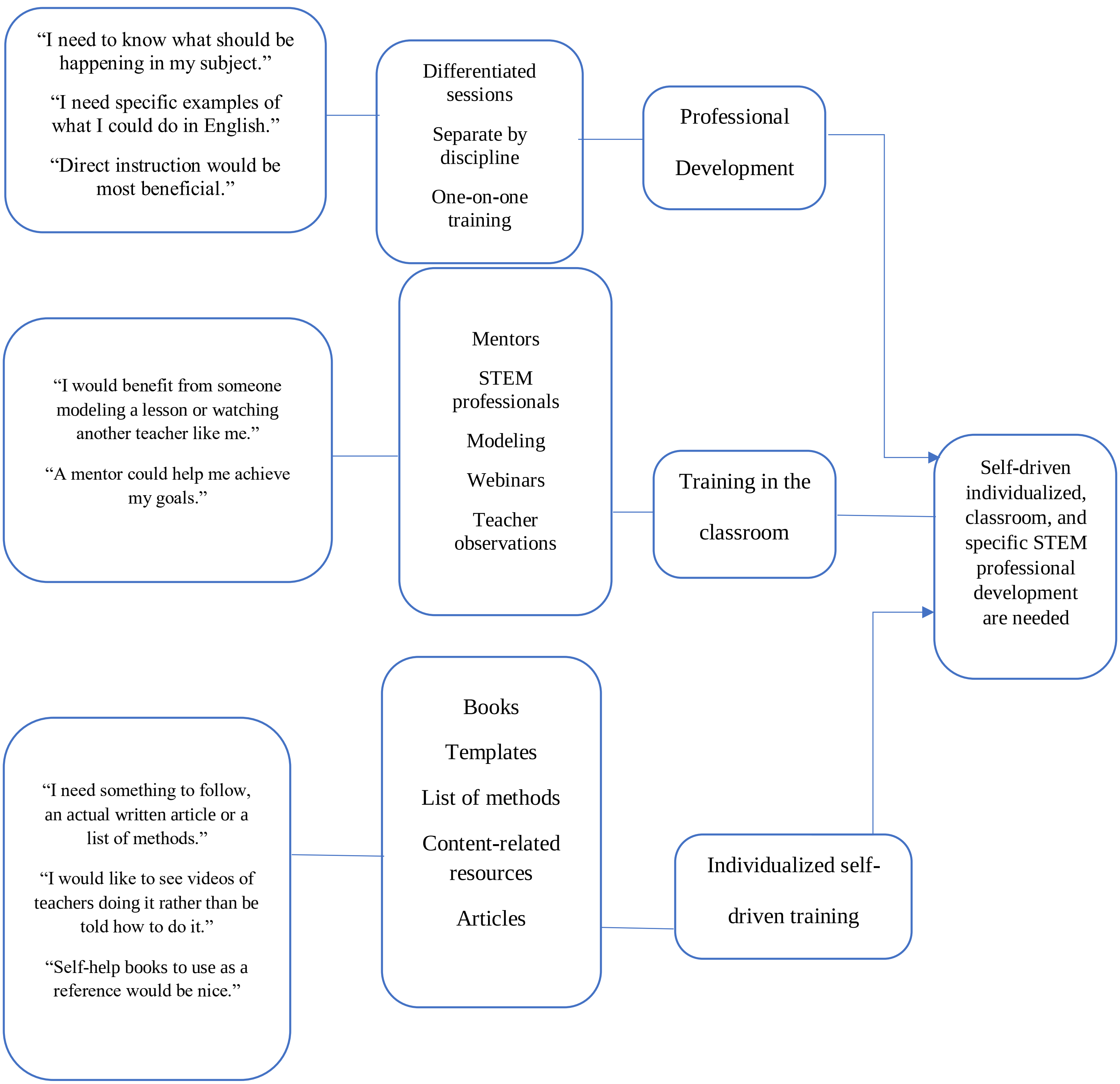


Table 4.22

Data Sorted in Levels of Coding for Research Question Three: What additional professional development do teachers need to feel comfortable incorporating STEM into their lessons?

Raw Data	Open Coding	Axial Coding	Selective Coding



Summary

Chapter 4 details an examination of survey data, interview data, and observations. The purpose of this study was to determine secondary teachers' perceptions of integrated STEM education, current level of STEM implementation, and types of professional development necessary for teachers to increase their level of confidence when implementing STEM teaching methods. For this study, data was collected from STEM and non-STEM educators in an East Tennessee secondary school. Analysis of the gathered data assisted in answering the following research questions:

1. By what methods do teachers in a traditional high school setting incorporate STEM teaching methods into their instruction?
2. What are the perceptions of traditional teachers regarding the STEM curriculum?
3. What types of professional development do teachers need to successfully integrate STEM teaching methods into their lessons?

Data were gathered using a survey, semi-structured interviews, and classroom observations. The data was analyzed to determine shared themes. From the participants, three themes emerged regarding the types of teaching methods being implemented in the traditional classroom: current professional development, activities to promote engagement and enhance instruction, and STEM teaching methods. Three themes became evident concerning the perceptions of teachers in relation to STEM education: lack of time to implement STEM activities, lack of relevant professional development, and lack of confidence in the ability to integrate STEM teaching methods. When analyzing the data related to types of professional development needed to successfully implement STEM, three themes were identified: specialized professional development sessions, training in the classroom, and individualized, self-driven training. Chapter

5 details the qualitative research findings, inferences, and conclusions developed from this data along with recommendations for future investigations.

CHAPTER 5: CONCLUSION, IMPLICATIONS, AND RECOMMENDATIONS

The fifth chapter is separated into four sections to examine the results of this qualitative study. First, the summary of the study is presented, followed by an investigation of the findings compared with the available literature. The third section describes the implications of the study. The final section presents recommendations for future research related to teachers' perceptions of integrated STEM education.

Summary of Study

The effect of STEM education on academic achievement and the development of essential critical thinking skills has been researched in many studies (Cabi, 2018; Cukurbasi & Kiyici, 2018; Fredericks & McColskey, 2012). Numerous studies related to the benefits of integrated STEM education include an investigation regarding positive effects on test scores and college acceptance rates, but there is an absence of research associated with teachers' perceptions and the steps necessary to improve the delivery of STEM curriculum. The purpose of this qualitative study was to investigate secondary teachers' perceptions of integrated STEM teaching methods, current level of implementation, and professional development needed to increase the effectiveness of the delivery of STEM curriculum. The data collected and analyzed from this study also suggests methods that school districts should consider when building the confidence and abilities of traditional teachers. To achieve triangulation, data were collected from semi-structured teacher interviews, an online questionnaire, and classroom observations.

A total of 20 secondary teachers of various disciplines within the research school responded to the questionnaire. The questionnaire asked participants if they were willing to participate in an interview or classroom observation for the purpose of gaining additional information concerning the perceptions of integrated STEM education. From the participants who agreed to be interviewed, six teachers were selected using purposeful sampling to include a variety of disciplines. Classroom observations were conducted with the interviewed teachers to further enhance the study. The analysis of data from this study offers an improved understanding of secondary teachers' perceptions of incorporating STEM teaching methods in a traditional classroom. This qualitative study was driven by the following research questions:

1. By what methods do teachers in a traditional high school setting incorporate STEM teaching methods into their instruction?
2. What are the perceptions of traditional teachers regarding the STEM curriculum?
3. What additional professional development do teachers need to feel comfortable about incorporating STEM lessons into their curriculum?

Findings

All study participants work in a public, secondary school in East Tennessee. A thorough analysis of data collected from an online questionnaire, semi-structured teacher interviews, and classroom observations provide answers to the qualitative research questions. The findings of this study are based on the triangulation of three distinct sources: online questionnaire, teacher interviews, and classroom observations. To increase the integrity of the study, member checks, peer debriefing, and triangulation were used during the research procedure. The following is a summary of the findings associated with each research question and the themes developed from the interview transcripts, online survey, and classroom observations.

Research Question One: Current Level of STEM Implementation

All survey participants indicated some degree of STEM implementation. In addition, the six observed teachers also incorporated STEM methods into their lessons. Following the observations, the interviewed teachers' knowledge of what STEM methods they were applying varied, but three distinctive themes were developed from the data collected. The themes are: STEM teaching ideas are supplemented with the help of a STEM coordinator, STEM methods are incorporated in the form of projects, and activities are used to promote engagement and enhance instruction.

Traditional teachers require the involvement of a STEM coordinator to assist in the implementation of STEM lessons. It is the responsibility of the STEM coordinator to be knowledgeable of current best practices in inquiry and STEM education. Interviewed teachers expressed the need for more collaboration and more resources to be provided for STEM lessons. Currently, the ideas and emails from the STEM coordinator are provided to those who teach STEM disciplines. Non-STEM teachers rely solely on the training provided by the district or the school. Interviewed teachers stated they had attended minimal amounts of professional development involving STEM training and expressed the need for additional professional training opportunities.

Interview participants also permitted the researcher to observe one lesson. During each of these lessons, STEM methods were being implemented to some degree. Traditional teachers were knowledgeable of the more popular STEM methods such as project-based learning, inquiry-based problems, cross-curricular connections, and the development of critical thinking skills. All six interviewed teachers supported the idea that project-based learning and inquiry-based tasks helped students develop the skills required to work through problems. Questionnaire responses indicated that all participants incorporated technology in the classroom. The school's newly implemented 1:1 initiative has provided the opportunity to enrich daily lessons with a laptop and access to modern software.

Data analysis also acknowledges the use of activities to promote engagement and enhance instruction. These methods are known as best practices to veteran teachers but also qualify as the incorporation of STEM teaching methods. Interviewed teachers were appreciative of the daily access to technology via student laptops and were excited to incorporate research-based projects into their curriculum. All surveyed teachers used small groups to enhance instruction and knew the importance of real-world connections. Multiple teachers expressed their support of using student-led projects to develop critical thinking skills.

Research Question Two: Perceptions of Traditional Teachers

Traditional teachers were also asked their views on the integration of STEM into their curriculum. All interviewed teachers agreed that it was necessary but expressed concerns regarding the implementation. Three themes emerged from the data collected from traditional teachers. The themes are: lack of time for STEM activities, lack of STEM-related professional development, and the lack of confidence in the ability to implement STEM.

All six interviewed teachers were open to the idea of incorporating STEM into their lessons. All six also expressed the same concern: no time. Due to the pressures associated with standardized testing, the teachers felt they had no time to stray from the delivery of content. One mathematics teacher said that she had so many standards to cover that she spent more time delivering them than actually using them. Teacher accountability places pressure on the teacher to push students to score high on standardized tests. In the event of poor scores, the teacher risks consequences such as forfeiture of monetary compensation, probation, and dismissal. The interviewed teachers feared that the implementation of STEM would result in the loss of precious class time needed to prepare for state testing. They all agreed that they would do what is best for their students if they knew how to find the balance.

The theme of professional development emerged across all types of data gathered. Surveyed teachers, especially those who teach non-STEM disciplines, agreed that there was a lack of STEM-related professional development available to them. Aside from general information presented at a PLC, teachers were unsure of what it meant to include STEM education. Data gathered during class observations showed that some methods were currently being used but unbeknownst to the teacher due to the lack of prior knowledge of STEM education. A common request among interviewed teachers was content-specific resources. Instead of a general lesson plan, teachers wanted specific STEM activities that were related to their discipline.

The theme of lack of confidence to implement STEM can be directly related to the amount of STEM training available. Teachers of non-STEM disciplines have difficulty relating the STEM disciplines to their content. During the interviews, a history teacher said that he thought STEM education was more geared toward science and mathematics. He also said that he was open to ideas and would like to see how it could apply to history. Technology knowledge is also an obstacle for teachers. Veteran teachers who began teaching before the monumental growth of technology did not have the opportunity to learn these skills during college. Numerous teachers are so uncomfortable with technology that they choose to not use it. More STEM-specific training would increase the confidence of teachers and promote the incorporation of STEM teaching in the classroom.

Research Question Three: Professional Development

When surveyed, all traditional teachers were open to learning new strategies to benefit their students. Teachers were asked to describe the types of professional development they would need to successfully incorporate STEM into their lessons. Three themes emerged from the data collected: STEM-specific professional development sessions, training in the classroom, and individualized, self-driven training.

The theme of STEM-specific professional development sessions emerged in both the questionnaire and the interview data analysis. Interviewed teachers stated that differentiated sessions and content-specific training would be beneficial. Several teachers were interested in incorporating STEM into their lessons but were unsure how to relate it to their content. Non-STEM teachers suggested sessions separated by discipline to allow more time for collaboration. General professional development was considered unbeneficial due to broad definitions of STEM education. Interviewed teachers wanted more content-specific resources to better model successful STEM integration.

A second theme to emerge among teacher participants was training in the classroom. Teacher participants indicated that watching model lessons conducted by STEM professionals would be helpful when designing their own STEM lessons. Additional support from a mentor was also something to consider for proper implementation and building confidence. Two interviewed teachers said that they would like the opportunity to observe teachers who successfully incorporate STEM into daily lessons, especially those who teach classes similar to their own.

The third theme, individualized, self-driven training, presented itself during the interviews. Four interviewed teachers stated that they preferred to learn on their own and at their own pace. When asked what type of professional development would be the most beneficial, these teachers suggested STEM teaching books, templates, lists of examples, and articles. Self-driven training was more appealing to them because they could seek content-specific resources that may not be presented in a general professional development session.

Implications

The findings in this study noted themes and ideas that secondary teachers associate with successfully implementing STEM in the classroom. From the findings, three implications can be constructed: Some STEM methods and activities are currently being implemented with the help of a STEM coordinator, traditional teachers have little time and training necessary for the integration of STEM education, and self-driven individualized, classroom, and specific STEM professional development are needed. The majority of participants acknowledge the importance of STEM education and its place in the classroom. All teachers interviewed displayed different levels of knowledge of STEM teaching but were open to learning new teaching strategies. The study also revealed that all traditional teachers would benefit from STEM-specific professional development and resources. Teacher participants recommended content-based collaboration with STEM professionals to become more knowledgeable of how to use STEM methods in their specific disciplines.

Recommendations for Further Study

With an increased need for STEM-graduates, the opportunities available for further research are abundant. This study focused on the perceptions of secondary teachers in regard to the implementation of STEM education in the classroom. Suggestions for future research include extending the study to other schools in the same district to gather data from teachers who teach in an elementary setting. The teachers who participated in this study were those who teach only freshmen and are departmentalized. By broadening the research sample, more feedback can be attained, and different perspectives would provide data that is relevant to those who teach lower grades. Another recommendation would be surveying another district. This study involved one school in a district in East Tennessee.

Summary

The purpose of this qualitative study was to examine secondary teachers' perceptions of the implementation of STEM teaching methods in the classroom. Overall, teachers lack the confidence to successfully incorporate STEM into their lessons. This can be attributed to the lack of exposure to relevant training and resources. Observations revealed that teachers are incorporating STEM to some degree even if they were unaware that they were doing so. Interview data revealed that 100% of teachers are willing to participate in STEM-specific professional development to learn about teaching strategies that are beneficial to their students. Participants also described the types of professional development they would need to acquire the skills required to efficiently teach STEM.

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Appendix A: Interview Questions

Interview Questions

1. What do you think of when you hear STEM education?
2. What do you think qualifies as STEM teaching methods?
3. How comfortable do you feel about incorporating STEM into your lessons?
4. What additional training do you need to be successful?

Appendix B: STEM Integration Checklist

Effective STEM Integration Checklist

Whatever form your STEM integration takes, there are a few important elements that will make it come alive for your students:

			?
1. **Involves all four disciplines: Science, Technology, Engineering, and Math.**			
2. **Is not just inclusive, but *integrated*. Each of the four disciplines involves core ideas, inquiry practices and crosscutting concepts.**			
3. **Uses projects and problems as learning vehicles, not just means of assessment at the end of a unit.**			
4. **Solves real-world problems of a local and/or global importance.**			
5. **Involves student-to-student collaboration.**			
6. **Challenges the students with “impossible” expectations. It’s OK to fall short when you’re reaching high.**			
7. **Makes it authentic – includes real practices and realistic careers.**			
8. **Requires students to reflect and revise.**			
9. **Includes criteria-based assessment from students themselves, peers and teacher.**			
10. **Includes student communication of findings, ideas and recommendations.**			