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Best teaching practices to increase student interest in STEM subjects

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BEST TEACHING PRACTICES TO INCREASE STUDENT INTEREST IN STEM SUBJECTS

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ABSTRACT

More than ever, jobs at all levels, not just for scientists, are requiring STEM knowledge and specific abilities that are associated with a STEM education (Lacey & Wright, 2009; Rothwell, 2013). Additionally, The Bureau of Labor and Statistics (Vilorio, 2014) reports that STEM occupations will continue to grow faster than other occupations. While the demand for jobs in STEM fields continues to grow, many of these positions remained unfilled due to an unskilled labor force. Students in the U.S. also pursue far fewer degrees in STEM subjects compared to other competitive countries (National Science Board, 2012). The results from the National Assessment of Educational Progress (NAEP, 2017a) reveal troubling information: students in America are continuously performing below their grade level in science and mathematics.

The literature review in this study highlights the significant impact students' early experiences in STEM education can have on their attitudes toward STEM education and the desire to pursue STEM careers. Therefore, to make STEM education desirable for all students, teachers must be aware of the effective classroom practices that promote STEM learning and interest at the K-12 level. This phenomenological study explored the best practices K-12 teachers integrate into the classroom to increase student interest in STEM-related subjects and promote STEM degree and career pursuance.

The researcher utilized a phenomenological design by conducting semi-structured interviews with participants who had direct experience with the phenomenon. The results from the interviews are intended to better inform K-12 teachers, administrators, and policymakers on the strategies to increase student interest in STEM-related subjects. Furthermore, this study is intended to bring awareness to the troubling number of students in the U.S. who do not have partial mastery of fundamental mathematics and science skills and concepts.

Chapter 1: Introduction

Background

It is critical for world leaders, such as the United States, to have a workforce prepared to meet the needs of today's society (National Research Council, 2011). Specifically, the 21st-century requires a workforce of individuals equipped with essential skill sets needed to meet the demands of an ever-evolving, technological society (President's Council of Advisors on Science and Technology, 2010). These skill sets include the ability to problem-solve, innovate, gather and evaluate evidence, think critically, and apply learned knowledge (U.S. Department of Education, n.d.). To develop these skills, primary and secondary school administrators and school policy-makers are focusing on improving the quality of Science, Technology, Engineering, and Math (STEM) education in the classroom (Gardner, 2017). However, while STEM subjects have grown in importance and have been a strong focus of educational reform efforts in the United States, there are still more vacancies in STEM jobs than there are individuals who are prepared for these careers (National Science Board, 2012).

STEM occupations have grown exponentially over the past years. For instance, between 2009 and 2015, employment in STEM occupations grew by 10.5%, or 817,260 jobs (Vilorio, 2014), and it is estimated that between 2014 and 2024, the number of STEM jobs will grow by 17%, as compared to 12% for non-STEM jobs (Bay Area Council Economic Institute, 2012). The Bureau of Labor and Statistics (Vilorio, 2014) reports that STEM occupations will continue to grow faster than other occupations. Furthermore, while wages for STEM occupations do vary, in 2015, 93 out of 100 STEM occupations had wages above the national average of $48,320 (Fayer, Lacey & Watson, 2017). It is clear that the demand for a workforce literate in STEM is growing, and that STEM jobs are financially rewarding.

While the demand for jobs in STEM fields continues to grow, many of these positions remained unfilled due to an unskilled labor force. By the end of 2018, there were nearly 2.4 million STEM jobs left unfilled (Smithsonian, 2019). The National Center for Education Statistics (NCES, 2019) proclaims that of the 1.8 million bachelor's degrees received in 2016, only 18% were in STEM fields. Subjects classified as STEM include degrees in the biological and agricultural sciences, engineering, social and behavioral sciences, mathematics, statistics, computer sciences, and physical sciences (National Science Board, 2018). At this rate, there will not be enough individuals in the STEM workforce to meet the demands in the U.S. Notably, according to a Pew Research Center survey, 52% of adults claimed that young people did not pursue a STEM degree because they thought the subjects were too hard (B. Kennedy, Hefferon & Funk, 2018). In a similar survey conducted by the Pew Research Center, non-STEM workers who were once interested in STEM careers were asked why they did not pursue their interest in STEM (B. Kennedy et al., 2018). Many individuals (27%) cited time and cost barriers, while 20% found another interest, and 14% had difficulty in STEM classes and lost interest (B. Kennedy et al., 2018). These results imply that the shortage of STEM proficient individuals in the workforce is primarily due to the lack of interest in STEM degrees at the undergraduate level. Therefore, if students continue to view STEM subjects as uninteresting or too difficult, the U.S. will not be able to hold its place as a global leader of technology and innovation (Maltese & Tai, 2010).

More than ever, jobs at all levels, not just for scientists, are requiring STEM knowledge and specific abilities that are associated with a STEM education (Lacey & Wright, 2009; Rothwell, 2013). The specific knowledge and skills desired by the majority of the workforce include the ability to analyze data, problem solve, analyze evidence, and apply learned knowledge. However, due to the shortage of students entering fields of STEM, industries are facing a lack of qualified employees. A survey conducted by Business Roundtable (2014) indicated that 60% of job openings require basic STEM literacy and 42% require advanced STEM skills. Furthermore, the survey revealed that 98% of CEOs claimed that the skills gap was a problem for their companies. These projections highlight the need to increase STEM literacy for all students, including those who do not pursue careers in STEM, and diversity in the STEM workforce.

More troubling, there are clear inequities in both access and success in STEM education among minorities. Populations that are not traditionally represented within STEM fields include African-Americans, Hispanics, and students from low-income families (National Science Board, 2018). Whites and Asians continuously have a higher representation in Science and Engineering degrees in the United States (U.S. Department of Education, 2016). Specifically, of the 18% of graduates who were awarded a STEM degree in 2016, 33% were Asian students and 18% were White students (U.S. Department of Education, 2016). Consequently, only 12% of STEM graduates in 2016 were Black, 14% Native American, and 15% Hispanic. Thus, Hispanics account for only 6% of employment in STEM occupations while Blacks account for only 5% (National Science Board, 2018). These disparities threaten the nation's ability to close education gaps and maintain its standing as the leading nation in research and innovation (U.S. Department of Education, 2016).

STEM education plays a crucial role in developing a competent STEM workforce. Specifically, research suggests that early experiences in STEM topics and the quality of STEM education, particularly at the K-12 level, is an important indicator of whether students pursue degrees in STEM-related fields (Tai, Qi Liu, Maltese & Fan, 2006). Therefore, examining the trends and indicators of student performance at the elementary and secondary levels may reveal insight on the quality of early education experiences in science and math classes.

The National Assessment of Educational Progress (NAEP) is a congressionally mandated program that has monitored changes in U.S. student's academic performance in science and mathematics for over 50 years. The national results reveal troubling information: students in America are continuously performing below their grade level in science and mathematics. In 2017, the NAEP (2017b) reported that only 38% of fourth-grade students and 34% of eighth-grade students performed at or above the proficient level on the science assessment. Furthermore, 24% of fourth-grade students and 32% of eighth-grade students performed below basic level on the same assessment, indicating no mastery of fundamental science skills. The NAEP mathematics results show similar outcomes, with only 40% of fourth-grade students and 34% of eighth-grade students performing at or above the proficient level on the mathematics assessment. Furthermore, 20% of fourth-grade students and 30% of eighth-grade students performed below basic levels of math proficiency. As a result, low assessment grades in early math and science education do not promote high participation in STEM subjects at the college level (Nail, 2011). These trends reveal that students in the U.S. have inadequate preparation in STEM subjects, which is, in turn, is causing low participation in STEM disciplines at the college level and a workforce untrained in STEM competencies. To conclude, the troubling NAEP results strongly suggest that there is an urgent need to change STEM instruction at the elementary and secondary level.

More than ever, education agencies and school educators are struggling to close the performance gaps within specific subjects, particularly in math and science. To generate meaningful change and improve the quality of STEM education, STEM education has also been a priority at the national level. Beginning early in his administration, President Obama prioritized educational reform, with a particular emphasis on improving STEM education (Handelsman & Smith, 2016). During his presidency, The Obama Administration made significant progress toward educational reform in science and mathematics, ultimately helping promote STEM education throughout the nation. Several notable achievements include:

- Launching the Educate to Innovate campaign and securing nearly $1 billion to support STEM education
- Incorporating STEM education as a priority of the Department of Education
- Receiving over 350 commitments from colleges and universities to provide pathways for underrepresented students to attain a STEM degree
- Starting the annual White House Science Fair
- Forming the Committee on STEM Education (CoSTEM), which comprises 13 agencies serving to coordinate Federal programs and activities to support STEM education. The committee focuses on five areas of improvement, including (a) STEM instruction in the K-12 level, (b) public and youth engagement with STEM, (c) STEM experiences at the undergraduate level, (d) services for underrepresented groups in STEM, and (e) curriculum design to better serve the STEM workforce (Handelsman & Smith, 2016).

According to a recent report by the Committee on STEM Education (2018), the Trump administration has also made significant strides towards developing a more literate STEM workforce. For instance, the administration directed agencies to prioritize STEM workforce education and training and established the President's National Council for the American Worker to raise awareness of the skill gap in STEM subjects. The Trump administration has also attempted to expand access to quality STEM programs at historically black colleges and universities.

Challenges in STEM Success

While significant strides have been made to provide students with meaningful STEM experiences in early education to help increase student interest in STEM subjects, more work must be done to identify the best teaching practices for doing so. Further instructional reform should take place at the K-12 level to increase interest in STEM subjects and attract more students to participate in STEM disciplines and careers. Since schools are failing systematically in providing quality STEM education, leaders in education must address the problem with systematic solutions. At the K-12 level, instructional approach, educators, and student socioeconomic background each play a crucial role in determining whether students will be interested in pursuing a STEM-related career, and whether students will have the appropriate training to succeed in these careers (Gardner, 2017; NRC, 2010).

Instruction approach in STEM. In its current state, STEM education is guided by a traditional pathway. Specifically, the teaching of STEM subjects is typically derived from a normative perspective, involving textbooks and lectures that are based on facts. These lectures are also, at times, combined with experiments that resemble recipes instead of discovery and problem-solving (Gardner, 2017). One way to attract more students to pursue careers in STEM at the undergraduate level is to move away from this lecture-based instructional approach. In particular, research suggests that students learn more in science and mathematics classrooms when instructors use active learning strategies rather than traditional, textbook-based learning (Freeman et al., 2014).

Additionally, students benefit most from an interdisciplinary approach to learning and coursework. A review by the National Research Council (2012) revealed that effective instructional strategies in STEM disciplines involve incorporating interactive lectures, group work, opportunities for formative feedback, and authentic problems and activities. In general, the report suggests that moving away from recipe-driven instructional approaches when teaching in STEM-related subjects, and toward more open-ended and student-driven experiences can motivate students to take an interest in math and science disciplines.

STEM educators. K-12 educators play a crucial role in preparing and inspiring students to pursue STEM-related careers. Policymakers even argue that the quality of a teacher could explain the variation in achievement among children (National Research Council, 2010). Specifically, teachers can impact and develop students' outlooks towards learning and affect the way they approach challenging subjects, such as math and science (Rivkin, Hanushek & Kain, 2005). STEM educators can change student outlook by teaching students a *growth mindset*, meaning that intelligence is not fixed, but rather can be developed with hard work (Walton & Spencer, 2009).

Furthermore, according to the President's Council of Advisors on Science and Technology (PCAST, 2010), great STEM teachers have two specific attributes: (a) deep content knowledge, and (b) strong pedagogical STEM training. When teachers are strong in these attributes, they can ignite student interest and inspire them for lifelong study in these fields. In summary, it is valuable to understand current research on what constitutes an exceptional STEM teacher when considering ways to prepare teachers to engage their students in STEM.

STEM education policies. There is a considerable achievement and participation gap among groups entering STEM fields. Many students from underserved populations, particularly

Blacks, Hispanics, Native Americans, and those from low socioeconomic backgrounds, are underrepresented in the STEM workforce (National Science Board, 2012). This is problematic, since having a STEM workforce that draws on a diversity of perspectives, cultures, and ideas can prove to be greatly beneficial to the nations global competitiveness (Page, 2007). Therefore, just as it is important to engage proficient students to pursue careers in STEM, attention should also be placed on finding effective teaching practices and policies to ensure low performing students of minorities are also reaching STEM proficiency.

Statement of the Problem

The United States is falling behind other nations in STEM education, both at the elementary and secondary levels (President's Council of Advisors on Science and Technology, 2010). As a result, while the global need for a scientifically, mathematically, and technologically literate workforce grows, the number of students pursuing STEM degrees at the undergraduate level continues to decline. As mentioned previously, nearly 18% of bachelor's degrees awarded every year are in STEM-related fields (U.S. Department of Education, 2016). Particularly, students in the U.S. pursue far fewer degrees in STEM subjects compared to other competitive countries, such as China and Japan, where over 50% of degrees are awarded in STEM fields (National Science Board, 2012). Moreover, not only are students in the U.S. pursuing careers outside of STEM disciplines, but there is also a high attrition rate in these areas of study, indicating that schools are failing to both attract and retain students pursuing careers and degrees in STEM-related disciplines (Tsui, 2007).

The National Center for Science and Engineering Statistics (2019) reports of a wide gap in educational attainment in STEM subjects between underrepresented minorities and Whites and Asians. For instance, in 2016, the NCSES found that 55.7% of science graduates were white, while only 13.5% were Hispanic and 9% African American (National Science Foundation, 2017). Limited access to resources and a lack of high-quality programs in math and science in low-income communities has hindered the preparedness and willingness of these minorities to succeed in careers that require STEM expertise (STEM Education Coalition, 2018). In order to increase the number of underrepresented minorities seeking degrees in STEM subjects, K-12 teachers, particularly those teaching in underserved communities, must provide an appropriate foundation in the science and math disciplines to motivate and prepare students for entry into STEM fields (STEM Education Coalition, 2016).

Policy makers, educators, and institutions agree that developing effective teaching strategies in early education plays a critical role in increasing student interest in STEM subjects and creating a competitive workforce with individuals trained in STEM disciplines (STEM Education Coalition, 2019). This evidence highlights the imminent need to determine successful teaching practices and strategies, specifically at the elementary and secondary level, to increase student interest in STEM disciplines, which would consequently encourage students to pursue careers in STEM. If left unaddressed, the gap in STEM workforce will continue to grow, leaving many talented students without STEM literacy and the skill sets needed to succeed in a 21st-century workplace.

Purpose Statement

The purpose of this phenomenological study is to explore successful teaching strategies and practices used by K-12 teachers to increase student interest and degree pursuance in STEM-related disciplines. This research aims to look beyond the foundational teaching requirements and closely assess the teaching practices that teachers of successful STEM programs implement in their daily instruction. Specifically, this study's purpose is to determine the following:

- The successful strategies and practices K-12 teachers employ to increase student interest in STEM subjects.
- The challenges K-12 teachers face in increasing student interest in STEM subjects.
- How K-12 teachers measure success of their practices in increasing student interest in STEM subjects.
- The recommendations K-12 teachers would make for future implementation of strategies in increasing student interest in STEM subjects.

Research Questions

The following research questions (RQ) were addressed in this study.

- RQ1: What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?
- RQ2: What challenges do K-12 teachers face in increasing student interest in STEM subjects?
- RQ3: How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?
- RQ4: What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?

Significance of the Study

The research suggests that it should be a national priority to inspire and prepare students of all backgrounds to excel in and pursue STEM fields. In 2012, it was reported that 26 other countries had more students obtain undergraduate degrees in science or engineering than the United States (Change the Equation, 2012). Creating a nation filled with scientists, engineers and innovators is key to driving economic growth and mainlining global competitiveness. To emphasize this need, in 2010, President Obama stated, “Our success as a nation depends on strengthening America’s role as the world’s engine of discovery and innovation” (Office of the Press Secretary, para. 3).

Research has linked the quality of K-12 STEM education to the level of scientific and economic growth in the United States, indicating the need to improve STEM education in the United States (President’s Council of Advisors on Science and Technology, 2010). For instance, in 2011, The National Research Council found that students who (a) had research experience, (b) undertook an internship, and (c) had teachers who connected content across different STEM courses, were more likely to pursue a STEM-related degree than their peers who did not have these experiences. Effective early STEM education, particularly at the elementary and middle school level, is an indicator of whether students will be attracted to STEM degrees. This study is intended to deepen the knowledge of the best practices that teachers incorporate in the classroom to increase student interest in STEM-related subjects, with the intent to have more students pursue and succeed in STEM-related degrees and careers. The results of this study can be utilized by educators and schools, and to also improve teacher-education programs and STEM policy initiatives.

Significance for educators. The results of this study can have great significance to K-12 educators and school administrators. Research suggests that students who have positive experiences in mathematics and science at the K-12 level are more likely to pursue a career in those fields. Teachers play a crucial role in fostering these experiences and are given the opportunity to teach in ways that would inspire students to take interest in STEM content and practices. However, although teachers play a crucial role in the success of their students, studies show that a high percentage of math and science teachers in middle and high schools are not certified in their respective subjects (National Research Council, 2010). Therefore, it is hoped that both novice and experienced teachers could benefit from this study. Teachers inadequately prepared to teach in these roles may utilize the results from this research study to be more effective at teaching STEM related subjects, and experienced teachers can use the results to better their own methods, or mentor new teachers.

Significance for teacher development. The findings of this study may be used to better prepare teachers during their initial training as well as during their teaching as professional development. While professional development does currently exist for STEM teachers, research suggests professional development programs are typically ineffective and do not address the specific needs of teachers or promote learning of STEM content and practices (Wilson, 2011). It would be more productive and beneficial for teachers to know, early on, the defining characteristics of the best teaching practices are that inspire their students to take interest in STEM-related subjects.

Significance for disadvantaged students. Well prepared teachers should be placed in all schools and classrooms, not just at those with outstanding reputations. Since funding for technology-enabled education is typically limited, schools with limited funds and resources may never have access to the technology (such as access to laboratory facilities, robotics kits, makerspace) that affluent schools have (President's Council of Advisors on Science and Technology, 2010). With proper knowledge of distinct instructional practices to promote STEM interest, without the use of expensive resources, teachers can help develop a well-qualified and diverse STEM workforce.

Significance for STEM initiatives. Policy makers and spear headers in STEM education reform could also utilize the results from this study to change the way STEM subjects are taught in elementary and secondary schools. As mentioned previously, The Obama Administration made several strides to improve STEM education at the elementary, secondary, and undergraduate level (Handelsman & Smith, 2016). However, there is room for more work to be done. By adding more information about the best teaching practices, particularly from the perspective of teachers, policy makers can use the results from this study to amend the requirements in science and mathematics classrooms and enforce proper training for STEM educators.

Assumptions of the Study

The following key assumptions guide this study:

1. Participants provided truthful responses to the interview questions.
2. Participants interviewed had successfully led students to pursue careers in STEM related subjects
3. The principal researcher bracketed out their own experiences with the subject and approached the coding process from an objective viewpoint.
4. Students from these schools pursued STEM careers primarily due to their elementary and secondary school experiences.

Limitations of the Study

There are several limitations associated with phenomenological studies that may impact the studies' outcome. The first limitation involves bias when interpreting the data (Janesick, 2011). According to Creswell (2018), the researcher must bracket their personal experiences, beliefs, and values about the topic, which is difficult to do at times. For instance, the principal researcher in this study has experience teaching mathematics and science at the K-12 level, which could have influenced her interpretation of the interviews. This limitation will be further discussed in Chapter 3. Second, the study was limited to teachers from top performing STEM institutions. School administrators and teachers from non-STEM specific schools were not represented. Therefore, participant experiences may not represent the broader population of teachers. Lastly, participant responses may hold biases based on their years of teaching experience, the city where they teach, and by their student's socioeconomic status and ethnicity.

Definition of Terms

- *21st century skills:* These skills include the ability to problem-solve, innovate, gather and evaluate evidence, think critically, and apply learned knowledge (U.S. Department of Education, n.d.)
- *Active learning:* Engages students in the process of learning through activities and classroom discussions, while emphasizing higher-order thinking, in order to construct knowledge and build scientific skills (Handelsman, Miller & Pfund, 2007).
- *Applied learning:* An educational approach whereby students explore subjects in a more personalized context, to help them apply what they have learnt in all facets of their lives (T. J. Kennedy & Odell, 2014).
- *Growth mindset:* When students understand that their abilities and intelligence can be developed (Dweck, 2008).
- *Phenomenological study:* An approach to qualitative research that describes the common meaning of a lived experience, or phenomenon, within members of a group (Creswell, 2018).
- *STEM skills:* STEM skills learned in the K-12 level include problem solving, creativity, inquiry skills, critical thinking, engineering-design thinking, and collaboration (Rothwell, 2013).

- *STEM literacy*: An individual's ability to apply his or her understanding of how the world works across the four interrelated domains of science, technology, engineering, and math (Katehi, Pearson & Feder, 2009).
- *STEM:* For nearly two decades, the National Science Foundation has used the acronym STEM to refer to the distinct fields of science, technology, engineering, and mathematics (Sanders, 2009).
- *Workforce diversity:* A workforce that includes a wide range of demographics, including underrepresented minorities, low-income individuals, and women.

Chapter Summary

Success in the 21st century is particularly dependent upon having a STEM-literate, modern workforce. Specifically, innovation capacity and national prosperity in the U.S. cannot be possible without an effective STEM education system. Multiple reports indicate that students of all backgrounds are increasingly not pursuing degrees and careers in STEM disciplines (NCES, 2019; National Science Board, 2018). As a result, enhancing the STEM workforce has become a national priority, especially for underrepresented groups. To make STEM education accessible and desirable for all Americans, teachers must be aware of the most effective classroom practices to promote STEM learning and interest in early education.

Chapter 1 introduced the intent of the study, which was to explore the best practices and strategies K-12 teachers integrate into the classroom to increase student interest in STEM-related fields. The goal is to increase participation in STEM-related careers, especially for groups typically underrepresented in the STEM workforce. Additionally, this study examines the challenges teachers encounter and recommendations for future implementation of the best practices to increase interest and involvement in STEM fields. The results of this study will help create a stronger STEM-literate workforce, particularly one that can meet the demands of the rapidly growing, technological society. Chapter 2 provides an overview of the existing literature on best practices to teach STEM subjects at the K-12 level. Lastly, Chapter 3 introduces the research methodology design, participant selection, and data analysis process.

Chapter 2: Literature Review

Status of STEM Education in the U.S.

STEM education linked to workforce skills. The science and engineering workforce plays a central role in fostering innovation, national prosperity, technological growth, and economic development and competitiveness in the U.S. (National Science Board, 2014). More so, as competing nations continue to make innovations in science and technology at rapid rates, the U.S. is in need for a STEM-literate workforce and population to make discoveries and advances that will contribute industries in the 21st century. Therefore, as the world continues to become more technological, the country's ability to remain a leader amongst other nations will be determined by the quality of STEM education in the U.S. (PCAST, 2010). According to the 2010 PCAST report, successful STEM education in the U.S. can (a) help produce a workforce capable of competing in a global marketplace, (b) ensure the U.S. continues to make discoveries that would advance understanding of our planet, (c) generate a pool of individuals who will create new ideas specific to the 21st century, (d) provide the quantitative literacy needed to make livable wages, and (e) strengthen the nation's democracy. Consequently, providing quality STEM education and opportunities to pursue STEM degrees is crucial to developing a STEM literate workforce.

STEM skills are needed in all areas of the American workplace, not just in science and technology occupations. For instance, in 2010, 16.5 million college-educated U.S. workers reported that their jobs require an undergraduate degree level of science and engineering training and expertise (National Science Board, 2014). These individuals worked in varying occupations not typically associated with science and engineering, such as sales, marketing, insurance, construction, and management positions. Notably, this was a 28% increase from the 12.9 million individuals who reported the same requirements in 2003.

Employers also agree that employees with STEM qualifications have valuable skills that are desirable to the workplace. For instance, after administering a survey to 1,065 employers, representing 450,000 employees across a variety of occupations, Prinsley and Baranyai (2015) discovered that the majority of employees agreed that individuals with STEM qualifications are valuable to their company, even when having a STEM background was not a prerequisite to their position. Additionally, the survey revealed that 71% of employers agreed that their STEM-literate employees are among their most innovative and adaptable to workplace changes. The employers also reported active learning, critical thinking, complex problem-solving, and creative problem-solving as essential skills and attributes of their employees. The National Association of Colleges and Employers (2019) conducted a similar survey across 172 employers, surveying them about their hiring plans for new college graduates. Respondents noted that the top four sought out attributes on a candidate's resume were written communication skills, problem-solving skills, ability to work in a team, and quantitative skills. Notably, the skills desired by employers as identified in both studies are those commonly associated with having earned a degree in a STEM-related field (U.S. Department of Education, n.d.).

In order to identify the specific characteristics that constitute of a STEM workforce, Carnevale, Smith, and Melton (2014) attempted to identify STEM knowledge, skills, and abilities that are related with STEM occupations. Based on a database of workers called the Occupational Informational Network, the researchers were able to identify the following competencies associated with STEM: the knowledge of mathematics, physics, chemistry, engineering, technology and design; skills such as critical thinking, active learning, complex problem solving, troubleshooting, and programming; and abilities, such as deductive, inductive and mathematical reasoning, and number facility. The researchers concluded that America is not producing enough STEM-capable students to meet the demands of both STEM and non-STEM occupations.

Narrowing pipeline of students pursuing STEM careers. The science and engineering (S&E) workforce has grown faster overtime than the general workforce. Specifically, between 1960 and 2015, the S&E workforce had an average annual growth rate of 3%, compared to a 2% growth rate of the overall workforce (National Science Board, 2018). Furthermore, STEM jobs are projected to continue to grow faster than other occupations (Vilorio, 2014). However, the NSB (2014) reports that while scientists and engineers are necessary for a "globally competitive and technology-intensive economy" (p. 5) and there is a demand for S&E occupations, there is not a sufficient enough workforce capable to meet the needs of the economy. For instance, by the end of 2018, there were nearly 2.4 million STEM jobs left unfilled (Smithsonian, 2019) and it is projected that by the end of 2020, 3 million STEM jobs will be left unoccupied (Lacey & Wright, 2009).

Prosperous S&E jobs may be left unfilled due to the decreasing number of students interested in pursuing a STEM-related college degree. For instance, only 18% of the 1.8 million bachelor's degrees received in 2016 were in STEM fields (NCES, 2019). The National Science Board (2018) classifies degrees in the biological and agricultural sciences, engineering, social and behavioral sciences, mathematics, statistics, computer sciences, and physical sciences as degrees in STEM. Plug in more info here. As mentioned previously, researchers attribute early student interests, student persistence in science and math courses, student attitudes, racial-ethnic backgrounds, and inadequate instructional approaches to the shortfall of individuals pursuing a STEM career (Maltese & Harsh, 2015; Maltese & Tai, 2010).

America is falling behind. To successfully be an innovative, knowledge-based economy, a workforce must have high levels of skills associated with STEM subjects (National Science Board, 2018). As mentioned previously, STEM education plays a critical role in developing a competent, STEM-literate workforce. Leading countries have recognized the need for a workforce equipped in S&E skills and have hence been heavily invested in both early and postsecondary STEM education to build STEM capabilities. According to the most recent estimates provided by the National Science Board (2018), 7.5 million bachelor's degrees in S&E fields were awarded globally in 2018. However, half of the degrees were awarded in two countries, India and China. In comparison to the U.S., 25% of the degrees were conferred in India, 22% in China and only 10% in the U.S. Furthermore, the number of S&E bachelor's degrees in China has grown significantly faster than any other developed nation, including the U.S. By failing to educate students in subjects that foster problem-solving, critical thinking, and communication skills, the U.S. is at an economic disadvantage in the global workforce (Wagner, 2008).

While other countries leading in technology and innovation are invested in developing a STEM-competent workforce and increasing their pool of S&E graduates, the U.S. is falling behind by not producing a sufficient pool of S&E graduates. Since research suggests that K-12 STEM education may be an important indicator of whether students pursue a STEM-related degree, examining the trends of student performance at the elementary and secondary levels may reveal insight on the quality of STEM education for students in the U.S. (Tai et al., 2006). Student achievement trends from the National Assessment of Educational Progress (NAEP, 2017a), the Trends in International Mathematics and Science Study (TIMSS), and the Program for International Student Assessment (PISA) will be analyzed to assess the national status of students in the U.S.

The NAEP is the most extensive national assessment that represents students' academic performance in mathematics and science. The test assesses student performance at grades 4, 8, and 12 to group students into four achievement levels: below basic, basic, proficient, and advanced. The 2017 mathematics report revealed a growing percentage of students performing at the below basic level, indicating nearly no mastery of fundamental mathematics skills (NCES, 2017). For instance, in 2017, 20% of fourth graders, 30% of eighth graders, and 38% of 12th graders achieved a level of below basic in mathematics. Notably, the percentage of students below basic has been steadily increasing for each grade level since 2009, while the percentage of students who achieved a level of advanced has slowly declined. Contrastingly, the percentage of students performing below basic level on the science assessment has declined since 2009, causing the percentage of students reaching proficiency to increase. However, the percentage of students below the basic achievement level is still alarming, with 24% of fourth graders, 32% of eighth graders, and 40% of 12th graders in the below basic range (NCES, 2017). The NAEP results indicate that a majority of students in the U.S. do not have partial mastery of fundamental mathematics and science skills and concepts.

The TIMSS and PISA assessments provide international comparisons on student achievement in mathematics and science, with the TIMSS focusing on academic content and PISA on students' ability to apply knowledge to real-world conditions (Harlen, 2001). According to the National Science Board (2018), the U.S. mathematics score among fourth-grade students on the TIMSS assessment was among the top 18, with only 10 education systems scoring higher.

Similarly, U.S. fourth-graders were among the top 14 education systems on the science assessment. The TIMSS result places the U.S. at a higher position than the PISA results. For instance, 36 education systems had a higher average score than the U.S. on the mathematics literacy assessment, and 18 had a higher score on the science literacy assessment. Since the goal of PISA is to assess the application of knowledge within a real-life setting, for the purpose of this study, the results may be more valuable than TIMSS.

The U.S. is failing to keep up with other nations in STEM education. As a result, the country is failing to produce qualified individuals to meet the technological, mathematical, and scientific demands of today's society (U.S. Council of Advisors on Science and Technology, 2010). The low scores on the national (NAEP) and international (TIMSS, PISA) assessments may be indicative of outdated curriculum, unproductive use of instructional time, and ineffective teaching in American schools (Merry, 2013; Wagner, 2008). To further investigate the divide between American and international students, Nail (2011) compared the quality and effectiveness of STEM instruction in Germany, the U.S., and Japan. His findings illustrated that "the United States teachers require students to use less high-level thought" (p. 2) than classes in Japan and Germany, where the focus was more on helping students gain understanding rather than skim through the information. As technology evolves, educators must be trained with the proper instructional approaches to teach STEM in early education to promote interest in STEM-related subjects at the college level.

National and Federal Recommendations to Improve STEM Education

As the evidence in the previous section suggests, current educational pathways are not successfully cultivating a culture of individuals interested in STEM subjects. As a result, the public is lacking in STEM literacy, which has led to an untrained STEM workforce. Several national and federal agencies have developed recommendations and reports to improve STEM education in the U.S in response to the need to enhance student engagement in STEM disciplines and inspire students to seek and excel in STEM careers. These agencies include The Department of Education, The National Science Foundation, the U.S. National Science and Technology Council's Committee on STEM Education (CoSTEM), The President's Council of Advisors on Science and Technology (PCAST), The National Academy of Science and Engineering, and the National Research Council (NCES, 2017). Additionally, during his two presidential terms, The Obama Administration prioritized STEM education by developing several plans and partnerships to help increase STEM literacy, heighten teaching quality of STEM subjects, and create educational opportunities for all of America's youth (Kanyane, 2013).

Collectively, the federal government, the private sector, and research communities have worked together to improve STEM education in the U.S. and boost the number of students pursuing and succeeding in STEM-based careers. Enhancing STEM education and finding effective ways to inspire more students to pursue careers in STEM are crucial to ensure the nation maintains its position as the leading nation in technology and innovation (Hossain & Robinson, 2012). The following section explores the existing recommendations and strategic steps endorsed by national and federal agencies and organizations.

Key elements of successful STEM schools and programs. In 2011, The National Research Council (NRC), with support from the National Science Foundation (NSF), was tasked with identifying highly successful K-12 STEM schools and programs. To carry out this charge, the NSF organized an expert committee named The Committee on Highly Successful Schools or Programs. The report identified the criteria that made for an effective STEM school or program, with the intent to make appropriate recommendations to leaders in school districts. The information was also useful to leaders in the national and state level to develop appropriate initiatives to improve STEM education.

The committee found that successful schools with effective STEM education provide instruction that captures students' interests and engages students in STEM practices throughout their schooling. Specifically, educators in these schools and programs capitalize on students' interests and provide them with opportunities to engage in practices that interest them. The committee notes that without dedicated teachers and support from the national, state, and local levels, this level of effective K-12 instruction cannot occur. As a result, the report identifies five key elements that can guide leaders in school districts, educators, and policy makers toward effective STEM instruction that promotes student interest in STEM subjects.

***A coherent set of standards and curriculum*.** In a final report from the National Mathematics Advisory Panel (2008), researchers discovered that top-performing countries present fewer topics but in greater detail compared to the spiral curriculum common in the U.S. Modifying math and science standards to a more rigorous curriculum that focuses on the deep expertise of topics may be an indicator of successful STEM programs. This system has already been seen as successful in some states. For instance, student outcomes improved in Minnesota when the state adopted common, rigorous standards and reduced the number of topics presented to students (Schmidt, 2011). Therefore, based on the existing research, the committee recommends that schools develop a coherent curriculum that emphasizes developing proficiency in key topics before introducing a new topic.

Teachers with high capacity to teach in their discipline. The second element of a successful K-12 STEM school or program is having teachers with both content knowledge and expertise in teaching that content (NRC, 2011). Although this may seem apparent, research shows that teachers are too often unprepared for teaching in their respective fields. For instance, in a research project examining out-of-field teaching in high schools, the researcher found that a third of secondary teachers who taught math did not have a major or minor in math, or of any other related discipline, nor were they certified to teach in math (Ingersoll, 1999). Therefore, to address this issue, through early preparation and effective professional development, teachers can develop their capabilities and knowledge to teach science and math subjects and have opportunities to work through problems they typically encounter in their roles (Cohen & Hill, 2000).

***A supportive system of assessment and accountability*.** In recent years, there has been a shift away from complex assessments in science and mathematics. Schools are now focusing on multiple-choice assessments, which is suggested to limit a teacher's ability to teach and assess in ways that promote learning (U.S. Government Accountability Office, 2009). To combat this issue, the NRC recommends developing a wide range of assessment strategies as well as a shared accountability system.

Adequate instructional time. Inadequate instructional time for mathematics and science subjects is another key factor of successful STEM education (NRC, 2011). In California, most K-5 teachers report spending less than an hour a week teaching science in their classrooms (Dorph et al., 2007). Since interest in STEM careers develop in primary school years, having inadequate instructional time for these subjects has grown of concern (Maltese & Tai, 2010).

***Equal access to high-quality STEM learning opportunities*.** Lastly, there are clear achievement gaps among students of varying socioeconomic and racial backgrounds. Factors that contribute to this gap include disparities in teacher expectations and unequal access to classroom resources and academic support (NRC, 2007). To improve STEM education for all groups, the disparities that hinder mathematics and science learning of underrepresented groups must be recognized and addressed.

In addition to the above findings, the NRC (2011) report also suggests that school conditions and cultures can support students in STEM learning. Specifically, schools that improved student learning showed strengths in school leadership, faculty professional capacity, parent-community ties, student-centered learning climates, and instructional guidance. This research highlights the need for providing instructional resources for teachers, improving STEM curriculum, and enhancing the capacity of high-quality K-12 STEM teachers. School districts, leaders, and policy makers can follow this proposal to improve K-12 STEM education across the U.S.

Federal STEM education strategic plan. In 2013, the Obama administration released a 5-year strategic plan for STEM education, detailing the federal government's strategy to improve STEM education in the United States. The document, prepared by the Committee on STEM Education (CoSTEM, 2013), is based on "a vision for a future where all Americans will have lifelong access to high-quality STEM education and the U.S. will be the global leader in STEM literacy, innovation, and employment" (p. 2). The Obama administration released the first report in 2013, and the Trump administration followed with their report with differing priorities in 2018.

2013 report highlights. The 2013 report highlighted five investment areas that were a priority for improving STEM education, along with a specific strategic plan of implementation in those areas. The five areas are to (a) improve STEM instruction by preparing 100,000 new K-12 STEM teachers by 2020, (b) encourage a 50% increase in the pipeline of students who have authentic STEM experiences, which includes an experience where students can engage directly in a hands-on, STEM-based activity, (c) graduate an additional one million undergraduate students with STEM degrees, (d) improve participation and better serve groups underrepresented in STEM fields, and (e) redesign graduate education to prepare students for a STEM workforce (CoSTEM, 2013).

To successfully see a change in the five areas of investment, the CoSTEM developed implementation roadmaps for each area. To satisfy area (a), the report highlights the need to educate and develop effective STEM teachers. Multiple sources indicate that top-performing teachers can make a significant difference in student achievement (Rivkin, 2007; Rockoff, 2004). Therefore, the report emphasizes the importance to develop, test, and support teacher development programs that encourage the use of practices that are known to provide students with hands-on STEM learning opportunities. As a result, more students would experience authentic STEM experiences between K-12 grades. Strategies to implement engagement in STEM subjects, area (b) involve investing in after-school STEM programs and improving an understanding, through further research, of how engagement in STEM experiences can improve student outcomes. The next area of investment, area (c), involves recruiting and engaging students in STEM majors. PCAST (2012) has identified several successful practices to accomplish this, including pedagogies, curricula, resources, mentorship, and academic support. To contribute to the pipeline of students enrolled in STEM programs, the CoSTEM suggests improving STEM education support at 2-year colleges, incentivizing university to industry partnerships, and exploring why there is a high failure rate at the undergraduate level in introductory mathematics classes. To satisfy area (d), schools must widen participation demographics and invest in efforts to change the climate of schools for underrepresented groups. Lastly, to prepare students to be literate in STEM and contributors to the STEM workforce, area (e), the CoSTEM proposes providing financial support to students who successfully contribute to STEM fields. In conclusion, the five-year strategic plan developed by agencies within the CoSTEM highlighted the imminent need to improve STEM education in the U.S. and provided strategies on how to successfully do so. Most importantly, the plan afforded a starting point for future presidential administrators to follow.

2018 report highlights. In 2018, under the Trump administration, the CoSTEM of the National Science and Technology Council released their second 5-year strategic plan for STEM education. Similar to the previous report, the 2018 report highlighted three goals: to (a) build a strong foundation for STEM literacy in the U.S. to better handle the technological changes and workforce demands, (b) increase STEM diversity by providing high-quality STEM education to groups typically underrepresented in STEM fields, and (c) prepare a STEM workforce by providing students with authentic learning experiences that would encourage them to pursue careers in STEM (CoSTEM, 2018). To achieve these goals, the CoSTEM recommended that the Federal government (a) develop and enrich strategic partnerships among institutions, employers, and communities; (b) engage students in learning by providing meaningful experiences where they can focus on real-world challenges; and (c) build computational literacy and thinking (CoSTEM, 2018). Through these strategic pathways, leaders in education and businesses can develop a shared vision for STEM literacy, innovation, and employment in the U.S.

The nation's progress. Both reports emphasize the importance of students' authentic STEM learning experiences, particularly in the K-12 level, as it may lead to an early interest in STEM subjects. Notably, the 2013 report emphasized the importance of teacher preparation, development and support more than the 2018 report. According to the 2018 annual report of the organization *100Kin10*, since launching the goal in 2013 to prepare 100,000 excellent STEM teachers by 2020, nearly 68,000 additional STEM teachers have been added in classrooms in America. The report also explored why there was a challenge in training and retaining STEM experts. After surveying thousands of educators, the researcher found 109 common challenges faced by teachers and grouped them into seven themes: Prestige, teacher preparation, elementary STEM, professional growth, teacher leadership, value of STEM, and instructional materials (100Kin10 Annual Report, 2018). Understanding the challenges of STEM educators is a fundamental step when determining the best teaching practices of STEM teachers.

STEM Pursuance Predictors

Increasing the number of U.S. students entering and completing degrees in STEM has become a national priority. This urgency has pressured researchers to uncover the specific factors that may lead to greater participation in these fields. As a result, a significant body of research exists that indicates several predictors that lead to participation in STEM fields, including student K-12 experiences, STEM teacher qualifications, student attitudes toward STEM, and student background.

Early experiences in science and math. An increasing body of research implies that students grow interest in STEM subjects and careers by the time they are in middle school (Daugherty, Carter & Swagerty, 2014l; Tai et al., 2006). Therefore, experiences at the elementary level in science and math, such as engagement and exposure, can be a strong predictor of whether students will aspire to pursue a career in STEM. Specifically, early and repeated exposure of STEM subjects can positively impact students' perceptions and cultivate a future interest in STEM degrees and careers (Hanover Research, 2012). For instance, a five-year longitudinal study by Archer et al. (2012) found that students' aspirations in STEM subjects are formed between the ages of 10 and 14. Furthermore, Habashi, Graziano, Evangelou, and

Ngambeki (2008) noted that a student's interest in STEM subjects could be redirected most when they are in the third grade. The researchers found that during this age students' interests were more flexible. In a study directed towards female learners, Brotman and Moore (2008) determined that female students who had hands-on STEM experiences at the elementary level were more likely to perform well in science courses and pursue degrees in STEM as undergraduates. As the evidence suggests, since students form an interest in STEM subjects at an early age, it is crucial to provide children with early exposure to STEM experiences. Moreover, great emphasis should be given to teacher development at the elementary level in science and math classrooms.

While student interest in STEM-related disciplines can be largely influenced at the elementary school level, experiences at the middle and high school levels are also of significance, as they can motivate students to explore a career in STEM (Hossain & Robinson, 2012). In a national study that tracked the interest in STEM careers for 6,000 students, Sadler, Sonnert, Hazari, and Tai (2012) discovered that STEM career interest near the end of high school was primarily predicted by interest at the start of high school. A more recent, extensive study that surveyed 24,000 students revealed that intentions to pursue a STEM career could drastically change between the 9th and 11th grade (Mangu, Lee, Middleton & Nelson, 2015). In summary, experiences in middle and high school years can serve to be a predictor of whether students pursue a career in STEM.

Another early experience that may affect student attitudes towards STEM subjects includes instructional time. While the previously mentioned research suggests the significance of elementary science and math education, recent reports indicate that teachers are not allotted enough science and math instructional time during the school day (Fulp, 2007). For example, during the 2011-2012 school year (the last for which data are available), third grade teachers in public schools spent on average 5.8 hours a week on Mathematics and only 2.9 hours a week on Science subjects (NCES, 2017). Moreover, time for science instruction has declined over the past 20 years (NCES, 2017). Notably, the analysis further indicates that students spent on average 1 hour less time on Mathematics and 1.5 hours more in Science subjects in eighth grade than third grade. These results are alarming since students with more class time per week tend to have higher scores than students in classes with less time (NCES, 2017). With such little instructional time dedicated to science and math, students may not be given adequate time and opportunity to have meaningful experiences in STEM subjects needed to ignite interest in a STEM career.

Student achievement in mathematics and science during secondary school can also have an impact on student interest and future pursuance of a STEM career. Previous studies that analyzed high school academic achievement and experiences have focused on the impact of course sequences (B. Schneider, Swanson & Riegle-Crumb, 1998), rigorous high school coursework (Adelman, 2006; Trusty, 2002), and high school grade point average (Ware & Lee, 1988). These studies revealed that more rigorous coursework could lead to more comprehensive proficiency in science than the number of courses completed. Furthermore, more rigorous coursework in high school was a key predictor in students' pursuance of a STEM degree (Trusty, 2002). For instance, when Maltese and Tai (2010) completed a two-part analysis of 4,7000 students to assess school-based factors that impact whether students choose to major in STEM, they found that students who had higher scores on middle school math and science assessments were more likely to complete degrees in STEM. Additionally, the researchers uncovered that students who completed geometry by the ninth grade were more likely to pursue and attain a degree in STEM.

Moreover, increased proficiency in STEM can lead to a positive STEM identity, which can impact student attitudes toward STEM careers (Vongkulluksn, Matewos, Sinatra & Marsh, 2018). Therefore, providing opportunities for success in STEM can have a positive impact on STEM career pursuance. To conclude, experiences in the K-12 levels, such as classroom coursework, instructional time, and teacher preparedness, can have a significant effect on STEM career interest and intent. Moreover, students typically find interest in STEM careers before graduating high school, and experiences during early education can serve as a strong predictor of intent to pursue a STEM career.

STEM teacher qualification. As mentioned previously, teacher influence plays a critical role in determining a student's career path towards STEM. Therefore, it is imperative that students learn from qualified, exemplary teachers equipped to teach STEM subjects. According to a study by Wieman (2012), effective STEM teachers should be able to accomplish the following:

- Connect with the prior thinking of the student to target individual student thinking and learning needs. This involves understanding the cognitive difficulties of the presented material.
- Embody a sense of ownership of the content in order to motivate students to pursue wide-range learning. The author suggests that this motivation may be accomplished by making the subject relevant to the learner and developing a sense of positive STEM identity in the learner.
- Provide timely feedback that straightforwardly addresses the student's thinking and help them overcome typical cognitive challenges associated with the subject.

- Understand how the human brain processes information in order to find methods to enhance long-term retention.
- Have a deep mastery of the content and understand how students learn the topic-specific content.

In summary, having deep content knowledge of STEM subjects is one fundamental attribute of a quality STEM teacher. According to a study by Ejiwale (2013), poor teacher preparation has inhibited the success of effective STEM education in the U.S. More so, according to the report, as a result of inadequate preparation to teach STEM subjects, teachers may have negative attitudes toward teaching STEM subjects and are not invested in STEM professional development. These factors, along with the occurrence of out-of-field teaching emphasized by Ingersoll (1999), have served as barriers to successful STEM education across the U.S.

***STEM content competence*.** STEM teacher content knowledge and preparation has been linked to increased teacher confidence and student achievement in STEM subjects (Bleicher, 2006). Epstein and Miller (2011) advocate the significance of having elementary math and science teachers who are prepared to deliver content-rich, engaging lessons, and also understand the importance of STEM. However, several reports indicate that traditional elementary teachers have a poor background and knowledge of STEM subject content. Since 1977, the National Science Foundation has sponsored a series of national surveys of science and mathematics education. The surveys were designed to "identify trends in the areas of teacher background and experience, curriculum and instruction, and the availability and use of resources" (Banilower et al., 2013, p. 1). The most recent report, released in 2012, surveyed 7,752 science and mathematics teachers across schools in the United States and had a response rate of 77%. According to the report, the majority of math and science teachers at the elementary level do not have a college degree in a STEM-related discipline (Banilower et al., 2013). Specifically, 11% of elementary science teachers have a degree in science, engineering, or science/engineering education, while 11% of elementary mathematics teachers have a degree in mathematics or mathematics education. Moreover, nearly 6% of primary teachers did not have any college science coursework. Sufficient preparation in science and mathematics content is critical in order to teach and promote lifelong interest in these subjects (Epstein & Miller, 2011).

Notably, middle and high school teachers have more extensive college coursework in math and science than elementary school teachers (Banilower et al., 2013). This is a significant finding since high school students taught by teachers who majored in the subject they are teaching typically outperform students who are taught by teachers who majored in another field (Wilson, Floden & Ferrini-Mundy, 2001). Additionally, teachers with more content knowledge tend to ask more demanding, engaging questions compared to those with less secure content knowledge (Davis, Petish & Smithey, 2006).

However, even with a more extensive STEM background, a 2003 survey revealed that 28% of teachers who teach science in grades 7-12 did not possess a minor or major in the sciences or science education (Ingersoll & Perda, 2010). More recent results indicate that among all high school science teachers, biology teachers are better prepared to teach their respective subject; nearly 65% of all high school biology teachers have a degree in their field, while only 24% of physics teachers have a degree in physics (Wingard, 2019). While these results suggest that most high school teachers have deep content knowledge in the STEM subjects they teach, the evidence suggests that there is still an overwhelming number of teachers who are not prepared to teach in these subjects.

STEM teaching preparation. There is evidently great concern about the adequacy of current math and science teacher preparation, particularly for K-8 teachers. In 2001, the Conference Board of the Mathematical Sciences reported guidelines for the preparation of mathematics teachers. The report emphasized the significance of preparing mathematics teachers who have extensive problem-solving and mathematical-reasoning skills. However, according to data collected by Editorial Projects in Education, 33 states require high school teachers to major in the subject they teach, while only 3 states have the same requirement for middle school teachers (NRC, 2010). In regard to teachers seeking elementary or middle school certification, 4% of programs do not require any mathematics courses to attain a certification and 63% require one or two mathematics courses. The combination of the lack of mastery of STEM subjects by teachers along with the poor, state-level coursework requirements has contributed to a pool of teachers unprepared to teach in these subjects.

***STEM teaching anxiety*.** In addition to the decreased time elementary school teachers dedicate to STEM subjects mentioned previously, teacher characteristics, such as comfort level and experience, may also impact early student experiences and attitudes toward specific subjects. For instance, due to their minimal content background in science and mathematics subjects, elementary teachers typically feel uneasy and unprepared when teaching STEM lessons. According to the 2012 National Survey of Science and Mathematics Education results, when teachers were asked to rate their content preparedness in specific subjects they taught, only 39% of teachers reported feeling well prepared to teach science, and merely 4% felt prepared to teach engineering (Banilower et al., 2013). Researchers have identified elementary teacher's lack of confidence to be as a result from insufficient STEM knowledge and pedagogical content knowledge, which will be further analyzed later in the literature review (Nelson & Landel, 2007).

This lack of confidence may be attributed to the common occurrence of out-of-field teaching, more frequently seen in high-poverty schools (Ingersoll, 2002). According to Ingersoll (2002), out-of-field teachers are those whose academic coursework and training does not match with the subject they are teaching. Precisely, they do not possess a bachelor's degree or minor in the subject they are teaching. During a 2002 exploratory study of unqualified secondary teachers, Ingersoll found that out-of-field teachers taught 37.6% of mathematics classes and 28% of science classes in high-poverty high schools. Notably, classes with high-poverty and minority students were much more likely to be assigned an out-of-field teacher than classes in low-poverty and minority public schools. Specifically, mathematics and science classes in low poverty schools were 46% more likely to be assigned an out-of-field teacher, and 40% in low minority schools. Lastly, the total percentage of secondary public-school science teachers without a major in science was 19.9%, and 31.4% for mathematics teachers. The results from this study reveal that although students of all backgrounds are exposed to out-of-field teachers, students of minority and from low-income schools are more likely to be assigned an unqualified STEM teacher.

Furthermore, a teacher's lack of confidence while teaching in out-of-field subjects may be linked to their anxiety about STEM education. Teacher anxiety is problematic since teacher anxiety while teaching STEM subjects may, in turn, impact their students' perceptions of their own STEM abilities (Beilock, Gunderson, Ramirez, Levine & Smith, 2010). The results of the various teacher analyses highlight the reality that elementary teachers are typically generalists with degrees in education rather than in a STEM field, further indicating the need to have teachers with more content knowledge in STEM at the elementary level, in order to provide more meaningful science and math experiences to students.

Teacher professional development. The lack of participation in the professional development of STEM teachers has been linked to poor student performance in these subjects (Ejiwale, 2013). Therefore, to serve as an effective teacher, researchers recommend ongoing professional development activities in STEM subjects as well as participation in mentorship by expert educators (Ejiwale, 2013).

In conclusion, many STEM teachers lack the content knowledge and the confidence to teach STEM subjects; yet, it is during these years that positive STEM experiences can serve as predictors for STEM career attitudes and pursuance. Therefore, more effort should be put in from teachers, school administrators, and leaders in educational policy to ensure teachers are qualified to teach in their respective subjects.

Student attitudes toward STEM. Beliefs about academic ability, such as confidence and self-efficacy, are positively linked to effort, persistence, and academic achievement (Bandura, 1997; Green & Miller, 1996). Bandura first linked students' motivation and achievement to how well they performed in a particular subject in 1986. This is evident more so in STEM subjects, where research suggests that students are more likely to pursue a STEM-related degree and career when they are confident in their academic abilities and have an overall positive attitude toward STEM (Degenhart et al., 2007; Tai et al., 2006; Wang, 2013). More so, high levels of self-efficacy and motivation are linked to an increase in enrollment and performance in STEM courses, as well as an increased likelihood of pursuing an undergraduate degree in a STEM-relate field (Simpkins, Davis-Kean & Eccles, 2006; Stevens, Olivarez, Lan & Tallent-Runnels, 2004). For instance, a study of 2,184 middle school students found that students who believed themselves smart or good in a STEM subject expressed positive attitudes toward their aptitude to pursue a STEM career (Degenhart et al., 2007). Similarly, students who viewed themselves as not good enough in a subject had more of a tendency to express dislike toward the subject, exhibit a negative attitude toward learning in the subject area, and found the subject either boring or too difficult.

In the high school level, Wang (2013) also found that students' attitudes towards math in high school were linked to their desire to pursue a STEM-related major in college. The cited research suggests the great impact students' beliefs in their academic abilities and motivation levels can have on STEM degree pursuance. Therefore, changing student beliefs about their academic aptitude may be an effective method to increase student interest in STEM subjects, and, in turn, the likelihood of them pursuing a STEM degree (LaForce, Noble & Blackwell, 2017).

Student background. Aside from student achievement, one of the most substantial barriers to entering a STEM discipline is academic preparation (Strayhorn, DeVita, & Blakewood, 2012). Therefore, while increasing student achievement in math and science has been a primary focus in STEM education reform, more attention should be directed toward access to courses among minority groups. Specifically, limited access to pre-college math and science courses and preparation in STEM subjects may lead to low achievement in future science and math courses, which may, in turn, prevent students from entering STEM fields.

Students of different racial-ethnic groups and socioeconomic backgrounds are provided with different course offerings and opportunities to learn (Tate, 2001). Therefore, a student's socioeconomic background, gender, and racial/ethnic group may also serve as a predictor of participation in a STEM field (Tyson, Lee, Borman & Hansen, 2007). Specifically, students of historically underrepresented racial groups and minorities are offered the most limited opportunities to learn (Strayhorn et al., 2012). For instance, the U.S Department of Education Office for Civil Rights (2016) reports that 48% of high schools offer Calculus, 84% offer Algebra II, 72% offer Chemistry, and 60% offer Physics. In addition to the limited course offerings of STEM subjects throughout the U.S., the analysis also indicated alarming disparities of learning opportunities among schools with different racial groups. Notably, of the schools with high populations of Latino and Black students, 33% offer courses in Calculus, 71% offer Algebra II, 65% offer Chemistry, and 48% offer Physics (U.S. Department of Education Office for Civil Rights, 2016). These results reveal the disparities of STEM course offerings within racial groups, further highlighting the reality that students do not have equal opportunities to enroll or achieve in STEM courses at the secondary level.

In addition to unequal opportunities for learning amongst varying racial-ethnic groups, Jerald and Ingersoll (2002) report that poor and minority students are twice as likely as other children to be taught by inexperienced and uncertified teachers. The U.S. Department of Education Office of Civil Rights (2016) report also supports the issue of teacher and staffing inequities in schools with high populations of Black, Latino, and American Indian students. Specifically, within the 2013-2014 school year, 7% of Black students, 6% of Latino students, and 6% of American Indian students attended schools where nearly 20% of teachers were in their first year of teaching. While that may not seem too alarming, when compared to the 3% of white and Asian students who attended these schools, it is a cause for concern. Moreover, Flores (2007) noted that the least-prepared teachers are in under sourced schools that are populated by racial-ethnic minority groups and low-income students from inner cities. It is evident that students of racial and ethnic minorities are deprived of access to quality teachers, which is, in turn, serving as a predictor of the lack of pursuance and success in STEM fields.

Not only are teachers of diverse students inexperienced in teaching, but many teachers are also not prepared with instructional strategies to teach diverse students. Gay (2013) brings this issue to light, noting that even when teachers are prepared, they may still possess attitudes and beliefs that resist embracing the diversity in a classroom. Additionally, some teachers may hold low expectations for students of minorities because of existing cultural stereotypes (Gay, 2013). As mentioned in previous sections, students who are taught by inexperienced and underqualified teachers, especially in STEM subjects, are less likely to reach achievement or pursue a career in a STEM-related field.

Lastly, students from different racial and socioeconomic groups typically begin school with different levels of preparation, which may persist throughout their education as they move to higher grade levels (Loeb & Bassok, 2007). This achievement gap is supported by research and was further revealed in the 2011 ECLS-K longitudinal study of children's development, which follows students' mathematics and science achievement once in kindergarten and again in third grade. The ECLS-K:2011 results revealed a gap of 6 points from the mathematics assessment between white and Black students at the beginning of kindergarten, followed by a gap of 13 points at the end of third grade (National Science Board, 2018). The results also noted a parallel gap in science assessment scores. Notably, the achievement gap between groups of different socioeconomic status was broader than that of different races. Specifically, the mathematics gap between students below and those at or above the federal poverty level was 9 points when students began kindergarten and 10 points by third grade. In short, disparities and inequalities among racial and socioeconomic groups manifest at the start of formal education;

specifically, students begin at different levels and are provided with unequal opportunities throughout their academic journeys.

Minorities and STEM

As mentioned previously, there are clear inequities and unequal learning opportunities in the participation, persistence, and retention of STEM subjects among minorities. Populations that are not traditionally represented within STEM fields include Blacks, Hispanics, Native Americans, and students from low-income communities. The U.S. Department of Education (2016) reports that minorities hold a disproportionately low share of STEM undergraduate degrees. During the 2015-2016 academic year, 33% of STEM graduates were Asian and 18% were white students, compared to the 12% that were Black, 14% Native American, and 15% Hispanic. That said, The National Science Board (2018) reports that the share of bachelor's degrees in Science and Engineering awarded to minority populations has increased throughout the years. For instance, between 2000 and 2015, the share of Science and Engineering degrees awarded to Hispanic students increased from 7% to 13%.

Since participation and persistence in STEM majors is low amongst minority groups, these groups account for a small percentage of employment in STEM occupations. In 2015, out of the 6.4 million workers employed in Science and Engineering occupations, 67% were white, 21% Asian, 6% Hispanic, and 5% Black (National Science Board, 2018). The data reveal that Blacks, Hispanics, and Native Americans remain underrepresented in nearly every major Science and Engineering field, both in schools and in the STEM workforce.

Not only do students of minority attain fewer degrees in STEM-related fields, there is also a considerable difference in their degree attainment rate compared to that of whites and Asians. Utilizing graduation trends from the Beginning Postsecondary Study (BPS) data source, a recent study by Riegle-Crumb, King and Irizarry (2019) investigated whether Black and Latino students who declared a STEM major were more likely to switch fields compared to white students. The study found that of the 58% of students who declared a STEM major attained a STEM degree, while only 43% of Hispanic students and 34% of Black students completed a STEM degree. In another report, Blacks were mostly likely (36%) to switch their major to a non-STEM field while Asians were the least likely (22.6%) to do so (Chen, 2013). In short, the results from multiple researchers reveal that Black and Hispanic students are more likely to exit a STEM major than whites.

While students of all backgrounds who enter undergraduate STEM disciplines have a lower graduation completion rate than students in non-STEM disciplines, graduation completion rates within STEM subjects considerably vary amongst different racial-ethnic groups. A 2010 analysis by the Higher Education Research Institute found that 24.5% of White students and 32.4% of Asian students majoring in a STEM subject completed their degree in four years, while 15.9 % of Latinos, 13.2% of Blacks, and 14% of Native Americans completed their degree in 4 years. The researchers also examined 5-year completion rates among racial-ethnic groups, which revealed an even wider completion gap. The results indicate that 33% of white and 42% of Asian students completed a STEM degree within 5 years, while 22.1% of Latino, 18.4% of Black, and 18.8% of Native American students graduated with a STEM degree after 5 years. The results indicate that an alarming percentage of Black, Latino, and Native American students are taking longer to complete their STEM degrees than their white peers.

Strayhorn et al. (2012) suggest three main factors that have contributed to the underrepresentation of minority racial/ethnic groups in STEM fields: lack of academic preparation, negative perceptions of STEM careers, and unsupportive STEM classrooms and environments. As mentioned in the previous section, not all students have equal access to learning opportunities, particularly in math and science courses at the high school level. Particularly, students of historically underrepresented racial groups and minorities are typically offered fewer courses in science and mathematics and in general, more limited opportunities to learn compared to their White or Asian peers (Strayhorn et al., 2012). Adelman (2006) emphasizes the severity of this issue after having found that the academic intensity and coursework in high school was a more prevailing predictor in their ability to attain a degree in a STEM subject than any other pre-college factor. Aside from academic preparation and opportunity, student perceptions of STEM careers may also contribute to the lack of participation of minority students in STEM subjects. Research also indicates that students of minorities perceive science, and scientists, to be a field for old, white males (Finson, 2002). Lastly, students have been seen to exhibit higher levels of commitment and interest to STEM fields when they received support from individuals of similar racial/ethnic backgrounds (Grandy, 1998). Furthermore, not having a positive role model from the same minority group may inhibit success in a STEM field and contribute to an uncomfortable academic environment for the student (Seymour & Hewitt, 1997).

To conclude, increasing the participation and success of racial and ethnic minority students in STEM fields is essential to maintain America's competitiveness in the global marketplace (Palmer, Davis, Moore & Hilton, 2010). Chang (2007) suggest the importance of having a more diverse body in STEM fields, as it may lead to a workforce of individuals who are equipped to manage and thrive in today's diverse workforce. With a diverse workforce, individuals can contribute to new discoveries and help maintain America's status as a leader in innovation.

Instructional Practices in K-12 STEM Classrooms

As previously mentioned and emphasized in this literature review, a significant amount of research suggests the critical role teachers play in influencing student interest in STEM disciplines (Ejiwale, 2013; Epstein & Miller, 2011; Ingersoll, 1999; NRC, 2010). For instance, in a meta-analysis conducted by the Institute of Engineering and Technology (2008), 300 peer-reviewed articles were analyzed to determine the influencers that impacted middle school students' development of interest in mathematics and science. Notably, the majority of students cited good teaching and parent influence as the two main reasons they became interested in STEM subjects, and a boring, irrelevant curriculum for the reason that they did not want to pursue STEM subjects. Consequently, teacher influence plays a critical role in developing STEM interest and a student's decision to pursue a STEM degree and career.

In 2010, the President's Council of Advisors on Science and Technology (PCAST) declared that great STEM teachers had two specific attributes: (a) deep content knowledge, and (b) strong pedagogical STEM training. According to the report, collectively, these two attributes can help teachers prepare and inspire students in STEM education. Furthermore, pedagogical mastery specific to STEM topics is a fundamental quality of effective STEM teaching. Previous sections of this literature review highlighted the importance of teacher content knowledge as it relates to student achievement and interest in STEM education. The following section will disclose the importance of having strong pedagogical STEM training and its integration with subject-specific content knowledge.

Current practices in STEM classrooms and the need for reform. STEM education in the U.S. is typically guided by a traditional teaching pathway, involving textbooks and lectures that are based on facts (Gardner, 2017). Furthermore, classrooms are traditionally teachercentered, led by lecture-based instruction, where students participate in classroom discussions that are driven almost entirely by the teacher (Gutstein & Peterson, 2005). This style of teaching commonly seen in classrooms is also associated with the transferring of knowledge, giving precise definitions, and providing firm answers (Tsai, 2002). However, research suggests that these traditional teaching methods do not promote student engagement, discovery, higher-order thinking, or problem-solving and critical thinking skills.

According to Flinders and Thornton (2013), for information to fully resonate, students must find value in the concepts presented in the classroom and make learning relevant to their reality. More so, in the early 20th century, philosopher John Dewey (1938), an advocate of social learning, suggested that students learn best by doing and from meaningful experiences. Specifically, he believed learning was most effective, and students were most engaged when they solved problems through hands-on approaches in natural social settings (Williams, 2017). The work of psychologist Jean Piaget also much supports this form of instruction. Piaget (1928) advised teachers to provide opportunities for individualized work, where students could construct learning with minimal guidance, thus establish a productive learning environment where students can talk, argue, and debate. Similarly, Pualo Freire (1993) advocated that teachers create opportunities for students to engage in dialogue, hence allowing students to be involved in their learning. In short, rather than follow a standards-based, direct instruction style of teaching, administrators and teachers should consider designing STEM curriculum and instruction based on the implications of Dewey, Piaget, and Freire.

The argument for integrated STEM education. While some ambiguity surrounds STEM education and how classroom teachers may implement it most effectively, there is a significant amount of research suggesting the use of integrated STEM education to make learning more connected and relevant for students (Elliott, Oty, Mcarthur & Clark, 2001; Furner & Kumar, 2007). Integrated STEM education is defined as an approach to teaching STEM education through a combination of some or all four of the STEM disciplines (Sanders, 2009). More specifically, integrated STEM education models involve objectives that primarily focus on one subject, while involving contexts and connections from the other STEM disciplines (Moore et al., 2014). This is a promising approach since real-world problems are not isolated disciplines similar to how they are taught and introduced in schools. Instead, solving real-world issues demands the need for skills that integrates all four disciplines (Beane, 1995).

An integrated approach to STEM education may help teachers provide a more relevant and stimulating experience for content development, which may increase student interest and performance in these fields (Furner & Kumar, 2007). More so, an interdisciplinary method to STEM education may improve higher level thinking skills, problem-solving skills, technological literacy, and retention of the material (King & Wiseman, 2001; Morrison, 2006). Integrating science and math at the K-12 level has also shown to have a positive impact on students' non-cognitive learning outcomes, such as attitudes, motivation, and interest in STEM careers (Hinde, 2005; Hurley, 2001).

For instance, Becker and Park (2011) conducted a meta-analysis of 28 studies that investigated the effects of integrative approaches in STEM subjects. The results of their study (meta-analysis) revealed that integrative approaches have positive effects on student learning by demonstrating higher achievement in STEM subjects. Notably, the analysis also revealed that earlier exposure to integrated STEM curricula might lead to higher achievement scores. Lower effects of the integrative approached were noted at the secondary and college levels, indicating that this approach may be more fitting for younger learners. This finding is significant to elementary teachers and administrators who strive to develop student interest in STEM education at an early age. To conclude, multiple studies suggest that integrative approaches in STEM subjects can make STEM instruction and student learning more effective, particularly at the K-12 level.

Existing challenges to STEM integration. Although there is a growing body of research suggesting the benefits of an integrated STEM approach, there are still several challenges to successful implementation. For instance, many teachers report that they are unprepared to use STEM applications in the classroom and are often unwilling to change their beliefs and practices (El-Deghaidy & Mansour, 2015). According to Zubrowski (2002), STEM teachers' implementation of an integrated approach is dependent upon national curricula, educational trends, support from their school, and their perceptions towards the integrative approach. More specifically, Moore and Smith (2014) provide several detailed suggestions on areas that are needed to improve in order to achieve successful integration:

- Curricula development: Provide curricula that integrate STEM that are research-based with meaningful mathematics and science.
- Teacher and administrator education initiatives: Most teachers and administrators have not learned how to teach STEM through an integrated approach. Therefore, new models and programs should be developed to provide teachers and administrators with professional learning experiences to prepare them to teach and develop STEM integration learning environments.
- School change initiatives: Schools must undergo structural changes to allow students to learn the content of each STEM discipline as well as understand the interconnection between each subject.

- Policy initiatives: Just as society is ever-changing, policymakers must change and update the ways in which teachers educate their students. For most teachers, instructional approaches and subject importance is based on the high-stakes testing in language arts and mathematics subjects. The emphasis placed on improving scores on these assessments results in students not having learning opportunities in science, technology, or engineering courses in early education.

Therefore, to successfully implement an interdisciplinary approach to teaching STEM subjects, there needs to be close collaboration among STEM teachers, administrative support, a dedication to the school and the integrated approach, sufficient teacher planning time, and appropriate teacher training opportunities (Stohlmann, Moore & Roehrig, 2012). In summary, to provide meaningful learning, it is imperative that students see the interconnectedness of STEM subjects. Successful STEM integration in K-12 may help students learn more deeply, take an interest in STEM-disciplines, and provide access to future STEM careers (Moore & Smith, 2014).

Pedagogical content knowledge. Successful teaching and learning require teachers to have a deep understanding of the subject-specific content, as well as a thorough understanding of the teaching activities and strategies that help students understand the content deeply enough to be capable of asking exploratory questions (NRC, 1999). According to Shulman (1987), pedagogical content knowledge (PCK) underlies effective teaching. PCK is not equivalent to knowledge of a specific discipline combined with a generic list of teaching strategies; rather, teaching strategies differ across disciplines (Shulman, 1987).

Furthermore, PCK includes the knowledge of difficulties students may encounter as they learn a specific discipline, the learning trajectories students come across in order to achieve understanding, and a set of known strategies that may assist students with overcoming difficulties they may encounter (NRC, 1999). Shulman (1987) describes PCK as the "capacity to transform content knowledge into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (p. 15). Therefore, PCK is comprised of two components: instructional strategies and learning difficulties. The instructional teaching strategies are used to make the topic understandable while learning difficulties are comprised of teacher knowledge about student misconceptions and barriers to learning the subject matter (Shulman, 1987). Furthermore, Ball, Thames, and Phelps (2008) report that appropriate content knowledge should be aligned with both curriculum requirements and students' needs. Lastly, teachers with strong PCK practices ensure to plan their lessons and prepare resources that specifically target students' conceptual development (Cunningham & Sherman, 2008).

After conducting thorough research in PCK as it relates to science education, Kind (2009) uncovered three components that are involved in PCK development among novice teachers: classroom experience, in-depth subject matter knowledge, and having well-adjusted emotional attributes, such as self-efficacy and confidence. The National Research Council (1999) advocates the importance of teachers acquiring an understanding of PCK practices, particularly knowing a variety of strategies in ways various learners may develop STEM knowledge and skills. Since incorporating PCK strategies in the classroom has the capacity to increase student interest in STEM subjects (Harris & Sass, 2011), understanding how teachers develop PCK practices is of relevance to this study. To conclude, STEM teachers could benefit from developing PCK practices more actively to improve their teaching, increase student performance, prepare for the

21st-century workforce, increase retention of information, and promote higher-order learning skills.

Evidence-based teaching strategies. There is a significant amount of empirical research concerning the most effective strategies for teaching and learning STEM education. Notably, student learning can be considerably improved when teachers move from traditional instructional methods to more student-centered, interactive instructional approaches (Handelsman & Smith, 20164). For instance, Zemelman, Daniels, and Hyde (2005) list 10 best practices when teaching math and science and ten practices that should be decreased when teaching these subjects. The authors recommend diminishing the use of the following items:

- teaching by telling,
- routine memorization of rules and formulas,
- single answers and single approaches to solve for answers,
- emphasizing memorization over understanding,
- drill worksheets,
- testing for grades, and
- dispensing knowledge.

Instead, they suggest teaching approaches that are student-centered, interactive, and involve a high level of student engagement. Specifically, the authors suggest that student learning is best achieved with the use of the following strategies:

- manipulative materials,
- cooperative group work,
- subject-matter discussion and inquiry,
- questioning and conjectures,

- justification of thinking,
- writing for problem-solving,
- instruction through a problem-solving approach,
- technology integration,
- being a facilitator of learning, and
- assessment of learning during instruction (Zemelman et al., 2005).

In a report to former U.S. President Barack Obama, Holdren and Lander further testified that alternative models of instruction in STEM education could achieve learning outcomes more effectively than current instructional methods (PCAST, 2012). Specifically, the report notes that active engagement and learning by students in the classroom can "increase retention of information, build critical thinking skills, induce positive attitudes toward STEM disciplines, and increase retention of students in STEM majors" (PCAST, 2012, p. 17). According to D. W. Johnson, Johnson, and Smith (1998), active learning is a form of teaching pedagogy that maximizes individual and collaborative learning by having students work together to accomplish a shared learning objective. More specifically, Henderson, Dancy and Niewiadomska-Bugaj (2012) list four characteristics commonly associated with an actively engaged classroom: (a) the course is student-centered, (b) students observe phenomenon and build ideas through laboratories, (c) the course involves explicit training of reasoning, and (d) students remain intellectually active during the class. Central to each of these characteristics is involving students in designing a solution for a real-world problem through a series of open-ended, hands-on activities (Satchwell & Loepp, 2002). By providing students with authentic problems related to their surroundings, students are more likely to find meaning in their learning.

As mentioned previously, when teachers incorporate active learning strategies in a STEM classroom, students become engaged in their own learning, more connected to the subject matter, and have a higher level of retention (Henderson et al., 2012). For instance, a study led by Harwell (2007) revealed that 64% of middle school girls preferred to learn in an active way, such as by conducting experiments and through hands-on experiences. Notably and significant to this research study, strategies that incorporate active learning may increase retention in STEM knowledge and interest in pursuing a STEM-related career (PCAST, 2012).

More specifically, the instructional strategies commonly associated with classroom engagement, particularly in STEM inclusive schools, that have demonstrated efficacy with respect to student learning include: problem-based learning (PBL), project-based learning (referred to as PjBL in this literature review to not be confused with problem-based learning), inquiry-based learning, collaborative learning, and cooperative learning (Froyd, Borrego, Cutler, Henderson & Prince, 2013). In a more detailed systematic review of instructional practices, Thibaut et al. (2018) provide a theoretical framework to support integrated STEM education in secondary education. Specifically, the authors grouped instructional strategies with overarching aspects together to provide a narrower framework and prioritized those strategies that emphasized teacher guidance. As a result of their systematic review, the authors identified five categories of instructional elements most commonly seen in an integrated STEM classroom, which include the following: integration of STEM content, problem-centered learning, inquiry-based learning, design-based learning, and cooperative learning. Each of these strategies are student-centered, promote active learning, and advocate the use of authentic, real-world problems. Moreover, these approaches to teaching have proven to increase the learning of information, the retention of information, and higher-order thinking skills among students (NRC, 1999).

The suggested principles are also all supported by a social constructivist view on learning, which states that students learn best through social and cultural interactions and when they are actively engaged in the learning process (Ertmer & Newby, 2013). More so, a constructivist position assumes that knowledge can be transferred by involvement in authentic tasks anchored in meaningful contexts (Ertmer & Newby, 2013). Research suggests that constructivism provides a sound theoretical foundation for STEM pedagogy (Cakir, 2008; Savery & Duffy, 1994). For instance, the conclusions from the systematic analysis of existing literature on emerging approaches to STEM education conducted by Thibaut et al. (2018) further support social constructivism as the basis of STEM education. Of the 23 empirical articles reviewed in the study, the seven that mentioned an underlying learning theory for STEM education referred to social constructivism. The results further illustrate that learning is a shared experience that may be enhanced with active learning strategies. The following sections present a more thorough description of common constructivist instructional strategies that promote student learning, engagement, and interest in STEM-related disciplines.

Problem-based learning. A popular learning strategy to increase student engagement commonly seen in inclusive STEM schools is to focus on investigating, explaining, and solving authentic, real world problems (LaForce et al., 2017). Originally developed in medical schools, problem-based learning (PBL) is a term used for instructional strategies that encourage students to conduct their own research, integrate theory and practice, and apply learned knowledge (Savery, 2006). More specifically, in order to increase the meaningfulness of the content, a PBL curricula is typically designed around specific problems that would be similar to problems students may encounter in their future jobs. According to Barrows and Kelson (1995), PBL was designed to help students construct a knowledge base, develop problem-solving skills, develop self-directed learning skills, become effective collaborators, and become intrinsically motivated to learn. In PBL, teachers play the role of supporters and do not provide information related to the problem or any specific guidance (Savery, 2006). They simply coach students with suggestions for further inquiry while students pursue their own solutions to the problem. Lastly, to promote active intellectual and social engagement, PBL activities are typically conducted in small, collaborative groups (Mergendoller, Maxwell, & Bellisimo, 2006). Research indicates that small group discussions and debates in PBL activities may enhance problem-solving skills, heighten higher-order thinking, and promote knowledge construction (Brown, 1994).

PBL is an appropriate teaching approach for helping students become active learners because it allows students to develop strategies and construct knowledge through real-world problems and scenarios (Hmelo & Ferrari, 1997). However, most research concerning the effects of PBL has focused on medical and undergraduate students. For instance, a meta-analysis of medical students by Gijbels, Dochy, Van den Bossche and Segers (2005) found that compared to a traditional approach, PBL did not affect factual knowledge and a moderate effect on the application of knowledge. Similarly, a study by Hmelo (1998) showed that students learning through a PBL curriculum were more likely to produce coherent explanations to problems, use science concepts in their explanations, and construct knowledge to help them accurately solve problems. Nonetheless, due to its potential for motivating students and its emphasis on active learning, PBL has been of rising interest to K-12 educators (Hmelo-Silver, 2004).

Whereas most research has been directed to the success of PBL strategies in medical schools, there are also encouraging reports of effective use of PBL in K-12 education. Most of the research available on PBL and K-12 education has suggested that this instructional approach may increase student engagement and enjoyment of STEM subjects, especially for females and underrepresented minority groups (Cerezo, 2015). For instance, a recent study explored the effects of PBL strategies on the attitudes of students towards integrated knowledge learning in STEM at the high school level (Lou, Shih, Diez & Tseng, 2010). The results of the study firmly recommend the use of PBL in high schools, specifically indicating the following conclusions: (a) PBL strategies may enhance student attitudes toward STEM careers, (b) PBL strategies help students experience the meaning of integrated STEM knowledge, (c) students may gain more content knowledge through PBL, and (d) PBL can provide students experiences to apply knowledge.

Granted that the findings from this study were promising, other results have been mixed. As an example, when Visser (2002) compared the effects of PBL and lecture-based instruction in a high school science class, students exposed to PBL reported less motivation and lower learning outcomes than those exposed to lecture-based instruction. However, those students also recounted more confidence in their learning. While there is a lack of decisive evidence that PBL approaches are more effective than traditional approaches in the K-12 setting, PBL has grown in popularity in K-12 education as an effective way to engage students in the classroom (Hmelo-Silver, 2004).

Although PBL in K-12 education may be a promising method of effective teaching in STEM education, it poses numerous difficulties for students and teachers. First, since standardized testing is a high priority for most state-funded schools, adopting any type of student-centered instructional innovation is challenging. As a result, instead of concentrating on new, innovative instructional approaches that focus on understanding, teachers are encouraged to utilize instructional strategies that teach to the test (Shaver, Cuevas, Lee & Avalos, 2007). Additionally, without proper training, students and teachers may feel uncomfortable with the new responsibilities required by an unfamiliar teaching approach (Land, 2000). To illustrate, in a study by Simons, Klein and Brush (2004), teachers noted experiencing frustration with the amount of time it would take to plan and implement PBL experiences. Teachers may also experience frustration and unfamiliarity with assessing student learning during PBL experiences (Brinkerhoff & Glazewski, 2004). Therefore, in order to successfully integrate PBL within K-12 environments, both students and teachers will need guidance and support. To conclude, using PBL in K-12 education may be an effective way to engage students in STEM learning and provide them with the necessary skills to pursue a future career in STEM.

Project-based learning. Similar to problem-centered learning (PBL), project-based learning is a student-centered learning approach that promotes active learning and encourages students to come up with solutions through investigation (Thibaut et al., 2018). PjBL is considered a type of PBL where students learn based on a specific, authentic, open-ended client-based project (Beier et al., 2019). More specifically, PjBL engages students in learning through challenging tasks, or projects, that require students to investigate, make decisions, design, and determine a resolution. Students are typically provided with conditions of a desired end product while left with the opportunity to develop their own approaches to developing solutions (Blumenfeld et al., 1991). More specifically, according to Thomas (2000), PjBL has five central characteristics: (a) the projects are central to the curriculum; (b) key concepts of the project are typically challenging to students, which is a critical part of directing them to construct their own understanding of the discipline; (c) the project should not command use of an already learned knowledge; (d) projects are open-ended without a predetermined outcome; and (e) topics are realistic and not instructor-developed.

PjBL approaches have grown of importance in STEM classrooms since it supports the integration of multiple disciplines within each project and higher-order thinking (Capraro & Slough, 2013). In a comprehensive study, Boaler (1997) observed and interviewed students in a traditional-teaching school and a PjBL-based school to examine the differences in the quality of their learning. The researcher noted several differences in student attitudes and mathematics learning. For instance, while students at the traditional school noted that they found the curriculum to be boring and tedious, students at the PjBL school referred to mathematics as a dynamic subject that involved investigation. Additionally, students at the PjBL school outperformed students from the traditional school on the national examination and the conceptual questions the researcher provided. Most significantly, students from the PBL school developed more useful forms of knowledge and were able to apply the knowledge in a wide range of settings (Boaler, 1997).

Research also supports PjBL as an effective method to increase student motivation and interest. In a recent study, Beier et al. (2019) explored whether authentic PjBL affected student attitudes and career aspirations in STEM. The researchers concluded that engaging in at least one PjBL during the first year of college led to greater STEM skills efficacy and higher levels of career aspirations in STEM subjects. While Beier et al. (2019) focused on college PjBL opportunities, several other researchers noted similar findings at the K-12 level. For instance, in a study that measured PjBL effectiveness on third, fifth, and 10th graders classified as low in motivation, 82% of the students agreed that the projects they participated in helped increase their motivation, and 93% noted an increase of interest in the topics involved (Bartscher, Gould &

Nutter, 1995). Similarly, another study found that after students engaged in one semester of PjBL activities, their intrinsic motivation for the subject matter significantly increased (Helle, Tynjala, Olkinuora & Lonka, 2007). The existing literature suggests that students enjoy the experience of participating in authentic projects, and PjBL may impact student career aspirations and interest in STEM (Beier et al., 2019).

Although PjBL approaches have shown to be a successful method in increasing retention and engagement in STEM, there are several challenges associated with enacting a PjBL approach. For instance, students may face a lack of motivation and exhibit disengagement when participating in inquiry and may have trouble working together in small groups (Edelson, Gordon & Pea, 1999). Moreover, teachers who are content-focused may struggle with implementing PjBL curricula. A case study investigating teaching orientation beliefs and teachers' initial experience with implementing PjBL curricula in a mathematics classroom revealed that teachers believe students could not learn from project-based activities until they mastered foundational concepts (Rogers, Cross, Gresalfi, Trauth-Nare & Buck, 2010). Furthermore, mathematics teachers had trouble seeing how PjBL could help students master formal mathematics required by the school and state. Contrastingly, in the same study, science teachers who were career skills-focused experienced fewer struggles with implementing the PjBL curricula, believing that it would help students develop the crucial skills needed to become productive citizens and contributing members to the workforce. The results indicate that teachers' pedagogical and teaching orientations serve as a primary indicator of how they would implement a PjBL curriculum and that new instructional approaches frequently conflict with teachers' deep-rooted beliefs on teaching and learning.

Furthermore, it may be more challenging to convert mathematics content to a PjBL context than science content (Rogers et al., 2010). A recent study conducted by Jacques (2017) attempted to uncover the dynamics of a PjBL mathematics classroom. The researcher concluded that PjBL in mathematics classrooms, regardless of grade level, primarily integrates engineering principles with mathematics. For example, students may design real objects and learn mathematics (such as measurement, data, and fractions) through the process of building. Since PjBL implementation is more challenging for some subjects than others, future research should focus on how to integrate PjBL in all STEM disciplines, particularly mathematics, and teachers should consider using these findings to lead PjBL activities in their classrooms.

Inquiry-based learning. Evidence indicates that implementing an inquiry-based instructional approach may help students attain a deeper understanding of scientific content and therefore can increase student achievement and interest in STEM subjects (R.M. Schneider, Krajcik, & Blumenfeld, 2005). Inquiry-based learning first originated in science education, where students engage in hands-on activities and experiences to aid them in their discovery of new concepts and understandings (Satchwell & Loepp, 2002). Student inquiry occurs when students are provided with the opportunity to "find solutions to real problems by asking and refining questions, designing and conducting investigations, gathering and analyzing information and data, making interpretations, drawing conclusions, and reporting findings" (R. M. Schneider et al., 2005, p. 284). Fittingly, inquiry-based instruction has the potential to make students active learners and leaders, promote a higher level of participation and motivation, increase students' interest and understanding, and construct knowledge on their own (Kyere, 2016). Moreover, inquiry-based instruction allows students to construct their knowledge from experiences that are meaningful to them, providing them with the chance to take responsibility for their learning with the guidance of their teachers (Boyd, 2016). This approach fosters 21st-century skills, such as innovation and problem-solving, that are crucial to prepare students for college and career readiness (Barell, 2012).

Furthermore, there is an abundant amount of research that shows that inquiry-based instruction is more effective than conventional instruction (Minner, Levy & Century, 2010; Nail, 2011; Satchwell & Loepp, 2002). For example, in a study comparing the effect of an inquiry-based unit versus a traditional teaching approach in a Virginia school, Nail (2011) determined that an inquiry-based approach had a highly significant effect on the immediate understanding level of students and student retention of information. Similarly, a meta-analysis of over 130 studies found that inquiry-based instructional practices increase science and math content as well as critical thinking and problem-solving skills (Minner et al., 2010).

While inquiry-based learning has shown to promote knowledge construction, many teachers struggle with balancing lectures with hands-on instruction in the teaching of STEM subjects (Kyere, 2016). More specifically, math and science teachers hesitate to implement inquiry-based teaching due to challenges in (a) finding appropriate technique to promote learning, (b) being too dependent on instructional strategies, (c) classroom management, (d) using technology tool to support inquiry, and (e) the use of nontraditional assessments (Driver, Asoko, Leach, Scott & Mortimer, 1994). Additional research from R. M. Schneider et al. (2005) suggests that teacher enactment may be improved when teachers are provided with materials and detailed lesson plans that support inquiry-based learning activities. However, materials alone would not be sufficient to facilitate reform in STEM education; administrators must provide teachers with professional development opportunities and change school policies to support teacher learning (J. C. Marshall & Alston, 2014). Furthermore, after teachers have been adequately trained, they need to be given sufficient time to explore different teaching strategies (J. C. Marshall & Horton, 2011). Lastly, teachers require support from administrators and other faculty members and should be provided with opportunities to both observe and experience inquiry-based instruction (C. Johnson, 2007).

Collaborative learning. PBL, PjBL, and inquiry-learning each promote social learning and provide students with opportunities to become proficient in communication and collaboration. For instance, while students work on projects and brainstorm ideas in small groups, they are practicing active listening strategies, communication, negotiation, and teamwork (Bell, 2010). To further promote these skills, teachers can place more emphasis on collaboration and group work through collaborative learning. In collaborative learning, students are encouraged to structure their own group work while resolving group conflicts and questions without the teacher's assistance (Matthews, 1995). Students participating in collaborative learning activities do not receive prior formal training or guidance on how to behave in small-group settings. This learning style has shown to be an effective strategy to improve student learning and retain STEM content (Slavin, 1996).

More so, teachers report being familiar with and utilizing collaborative learning more often than other learning strategies. When Froyd et al. (2013) examined the use of several instructional strategies in engineering courses, they determined that 89% of teachers were familiar with collaborative learning strategies. Furthermore, of those teachers, 54% were currently using collaborative learning in their classrooms while others attempted but then stopped. To conclude, researchers agree that collaboration is a foundational skill to the success in any STEM discipline and STEM teachers should utilize collaborative learning strategies in all levels of education (Jensen & Lawson, 2017).

Cooperative learning. Another effective research-based instruction practice to teach STEM education is termed as cooperative learning. According to D. W. Johnson and Johnson (1994), in cooperative learning, students maximize their learning by working together in small groups to achieve a common goal. Contrary to collaborative learning, in cooperative learning, the teacher is an active participant in the learning process. For instance, while the groups are working on their task, the teacher visits each group to observe student interactions and may also intervene when appropriate (Matthews, 1995). Lastly, cooperative learning classes typically conclude with a brief summary session, where students provide a brief oral report of their findings.

Furthermore, D. W. Johnson and Johnson (1994) illustrate effective cooperative learning teams with five essential elements. The first element of cooperative learning is *positive interdependence*, also referred to as the heart of cooperative learning. In positive interdependence, team members perceive that they are linked together, in a way where one's success is not possible unless all members of the group succeed (D. W. Johnson et al., 2014). Teachers may establish positive interdependence in the classroom by (a) ensuring team members share mutual goals, (b) creating a system of joint rewards, and (c) assigning roles and responsibilities to team members (D. W. Johnson et al., 2014). Another critical element of cooperative learning is *individual accountability*, which occurs when teachers assess individual performance and provide the results to all group members. This process provides an opportunity for the group to know which members need more assistance with the assignment and helps students realize they cannot rely on their group members to do the work for them (D. W. Johnson & Johnson, 1994). The third element, termed *promotive interaction*, occurs when students encourage each other's success by assisting and praising their learning efforts. This element requires students to engage in discussion, share ideas, challenge each other's reasonings, and provide feedback to ensure that they stay motivated to complete their assigned tasks (D. W. Johnson et al., 2014). Cooperative learning also promotes *interpersonal and small group skills*. D. W. Johnson et al. (2014) advocate that the success of cooperative learning depends on these skills, and that "leadership, decision-making, trust-building, communication, and conflict-management skills have to be taught as purposefully as academic skills" (p. 94). Lastly, the fifth element of cooperative learning is *group processing*, which allows for groups to discuss their progress and identify ways to improve their learning process (D. W. Johnson & Johnson, 1989). The authors suggest that teachers allow for sufficient time for group processing to take place, ensure that all students are involved in the process, and communicate expectations clearly to the students. These five basic elements distinguish cooperative learning from other types of group learning. To conclude, teachers should understand how to implement these five elements to promote effective collaborative learning environments (D. W. Johnson & Johnson, 1989).

Numerous studies have investigated the benefits of applying cooperative learning practices in the classroom. Specifically, cooperative learning may (a) encourage students to be active participants in the classroom (Webb, Troper & Fall, 1995), (b) improve student achievement (Zakaria, Chin & Daud, 2010), (c) promote a deeper understanding of the content (Shimazoe & Aldrich, 2010), and (d) motivate students to learn (D. W. Johnson & Johnson, 1989). For instance, Zakaria, Solfitri, Daud, and Abidin (2013) attempted to determine student opinions of cooperative learning as well as the effects of cooperative learning on mathematics achievement in secondary schools. After sampling 61 students, the researchers concluded that there was a significant difference in student achievement between students who learned in a cooperative classroom and those who were taught mathematics using traditional teaching methods. Additionally, students subject to cooperative learning demonstrated a deeper level of mathematical understanding and self-confidence. In another study examining the effect of cooperative learning on student achievement and attitudes towards biology, Rabgay (2018) determined that cooperative learning methods increased 10th-grade scores in biology and improved student attitudes toward the subject. More specifically, students taught using cooperative learning methods showed increased interest, understanding, and satisfaction with their course (Rabgay, 2018). To conclude, cooperative learning is an effective method to increase student engagement, participation, responsibility, and academic achievement (D. W. Johnson & Johnson, 1989; Zakaria et al., 2013).

According to Honobein (1996), the pedagogical goals of a constructivist classroom include the following: (a) to provide experiences with the process of student-led knowledge construction, (b) to provide experiences with alternative solutions and methods, (c) to embed learning using authentic tasks, (d) to encourage student-centered learning, (e) to embed collaboration and learning as a social experience, (f) to encourage multiple modes of representation, and (g) to encourage awareness of the knowledge construction process by having students explain why or how they solved a problem a certain way. PjBL, PBL, inquiry-learning, collaborative learning, and cooperative learning support the suggested goals and can be incorporated to promote a constructivist-led classroom, which can, in turn, increase student interest in STEM subjects and allow students to attain a deeper understanding of STEM content.

Chapter Summary

While the demand for a STEM-literate workforce continues to rapidly rise in the U.S., there is a shortage of STEM proficient individuals available to meet these demands (Maltese & Tai, 2011). This shortage is primarily due to the lack of students interested in pursuing STEM-related degrees and careers (NCES, 2019). As analyzed in this literature review, several factors contribute to students' interest in STEM subjects and their ultimate decision to enter into STEM academic and career fields.

Early experiences in STEM-related subjects, instructional time, teacher qualifications, teacher pedagogical knowledge, student attitudes, and student backgrounds were several of the common themes identified in this literature review. For instance, research indicates that a strong STEM education and workforce begins as early as preschool and engages students with hands-on learning experiences that offer opportunities to interact with STEM professionals (U.S. Department of Education, 2016). It is evident that teachers also play a crucial role in developing STEM interest during these early experiences. Several scholars highlighted this role, indicating that STEM teachers should have both content knowledge of the subject they are teaching and expertise in teaching that content (Ingersoll, 1999; NRC, 2011). Content knowledge is typically associated with a teacher's academic preparation, such as having a degree in the subject they are teaching, while expertise in teaching the content relates to the teacher's pedagogical knowledge. More so, without adequate preparation to teach STEM subjects, STEM teachers may develop anxiety while teaching, which may, in turn, impact their students' perceptions about STEM (Beilock et al., 2010). Knowing the strategies, practices, and characteristics of a STEM teacher who is an expert in the field may help teachers, administrators, and policymakers create STEM-friendly environments that can increase student interest in STEM subjects.

Chapter 3: Research Design and Methodology

The purpose of this research study was to determine the best practices K-12 STEM teachers could employ to increase student interest in STEM subjects. The researcher determined that a qualitative research design (Creswell, 2005) was the most appropriate approach to uncover the best practices of STEM teachers. This chapter begins with a restatement of the research questions, followed by a discussion on the nature of the qualitative study, and a detailed exploration of the phenomenological methodology of the study. The researcher also outlined the design of the study, including participant selection, data source, human subject protection, and data collection processes and approaches. Since interviews are a key characteristic of phenomenological studies, this chapter reviews the interview protocol in detail, including the study instrument and the methods used to ensure validity and reliability. Additionally, the researcher addresses any personal biases about the subject. Lastly, this section describes the data analysis techniques used to extract the findings.

Re-Statement of Research Questions

This chapter describes the research methods that were applied to achieve the objectives of this study, which is to primarily answer these four research questions:

- RQ1 - What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?
- RQ2 - What challenges do K-12 teachers face in increasing student interest in STEM subjects?
- RQ3 - How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?

- RQ4 - What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?

Nature of the Study

This descriptive study utilized a qualitative approach to determine the best practices to increase student interest in STEM subjects. According to Creswell (2013), qualitative research uses distinct approaches to inquiry and places emphasis on the design of research. More specifically, qualitative research is a study that "begins with assumptions and the use of interpretive/theoretical frameworks that inform the study of research problems addressing the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2013, p. 44). Qualitative approaches do not utilize statistical interpretations; rather, research is constructed based on the use of interviews and observations (Gray, 2013). Researchers typically use a qualitative approach when there is a problem or issue that needs to be deeply understood, especially when the problem or issue is experienced by an oppressed group of people (Creswell, 2018; Patton, 2002).

There are several common characteristics of qualitative research, as outlined by Creswell (2013) and Hathaway (1995). First, researchers collect data themselves in a natural setting, specifically in the field site where the participants experience the problem being studied (Creswell, 2013). More so, to fully understand the phenomenon taking place, qualitative researchers engage what is being researched and make direct experiential contact with the particular phenomena (Hathaway, 1995). Therefore, qualitative researchers typically collect multiple forms of data, including open-ended interviews, observations, questionnaires, and document analysis (Creswell, 2013). After collecting the data, researchers group the responses into categories and themes to understand and describe the participants' experiences (Gray, 2013).

Furthermore, qualitative research involves inductive and deductive logic, requiring the use of complex reasoning skills. Since participant meanings on topics represent diverse viewpoints, qualitative researchers must develop themes that are based off the multiple perspectives from the participants, not meanings derived from the review of the literature (Creswell, 2013). Another essential characteristic of qualitative research is that it is a developing design; that is, as the researcher learns about the problem from the participants, the initial plan for research may change (Hathaway, 1995). Qualitative research is also reflexive in nature, where the participants share their backgrounds and topic interest to the participants (Creswell, 2013; Hathaway, 1995). Lastly, because qualitative studies involve reporting multiple perspectives and take into consideration the bigger picture, they are viewed as holistic (Creswell, 2013).

Strengths. There are several noted strengths associated with conducting a qualitative research study. First, scholars view a qualitative approach as an effective method to apply when attempting to deeply understand and explore a complex phenomenon (Creswell, 2013). Most of the time, the researcher collects data through personal experiences with the participants, such as through observations, interviews, and personal interactions (Anderson, 2010). These methods of data collection allow for the researcher to have the flexibility needed to comprehensively elicit the participants' stories. Moreover, qualitative research is valuable when analyzing data that is complex and not easily reduced to numbers (Anderson, 2010). For instance, by providing a better understanding of the nature of educational issues, qualitative research may provide insights into methods to improve teaching and learning and extend the scope of educational research (Anderson, 2010). Furthermore, since interview questions are open-ended, questions can be guided and redirected by the researcher throughout the interview (Creswell, 2005). Therefore, the research framework and direction can be revised in real time as the researcher uncovers new data. To conclude, qualitative research has numerous strengths and advantages over other approaches, especially when attempting to study a phenomenon in depth (Anderson, 2010).

Weaknesses. While there are numerous strengths to using a qualitative research approach, there are also several weaknesses and limitations to consider. Marshall and Rossman (2015) note that the most difficult part in writing qualitative research is presenting a clearly focused design for a study that typically emerges while the research is unfolding. More so, the quality of the research is highly dependent on the skills of the researcher, and data interpretation is easily influenced by the researcher's biases (Anderson, 2010). Therefore, it is often difficult to remove the researcher's own reflections and interpretations from the data (Gray, 2013). Also, since research findings are not tested for statistical significance, findings lack a degree of accuracy and conviction that is typically found in quantitative studies (Atieno, 2009). Due to this lack of assurance, some fields, such as within the scientific community, do not accept qualitative studies as surely as quantitative studies, and findings typically cannot be extended to wider populations with a high degree of certainty (Anderson, 2010; Atieno, 2009). Lastly, since there is a high volume of data involved in qualitative research, data analysis and interpretation can be very taxing on the researcher (Anderson, 2010).

Assumptions. According to Creswell (2013), researchers lead qualitative studies with four philosophical assumptions: ontological, epistemological, axiological, and methodological. The ontological assumptions relate to the researcher's view of reality, taking into consideration the multiple realities experienced by the multiple individuals involved in a qualitative study (Creswell, 2013). For instance, in this study, the researcher sought to report the different perspectives that emerged from participants and developed themes based on how the individuals viewed their experiences.

The epistemological assumption relates to how knowledge is known (Creswell, 2013). In this study, as with most qualitative studies, the researcher interviewed the participants in their natural setting to collect subjective evidence of their lived experiences. According to this assumption, the closer a researcher is to the participant, the better understanding they will have of the participants' perspectives (Guba & Lincoln, 1988).

The axiological assumption is characterized by the researcher making their values and biases known in a study (Creswell, 2018). More specifically, in a qualitative study, the researcher admits that data interpretation is shaped by their personal experiences (Creswell, 2018). In this study, the researcher reported her bias as a STEM educator and acknowledged the vital role it played in shaping her interpretation of the interview responses and data analysis.

Lastly, methodological assumptions refer to the research process and procedures (Creswell, 2013). As mentioned previously, qualitative research is "inductive, emerging, and shaped by the researcher's experience in collecting and analyzing the data" (Creswell, p. 21, 2018). Specifically, the researcher may continuously revise the research questions based on experiences and participant responses (Grossoehme, 2014). The researcher in this study used open-ended interview questions and prepared follow-up questions to use as needed.

Methodology

Creswell (2018) notes five approaches to qualitative research: narrative research, phenomenology, grounded theory, ethnography, and case study. The methodology used in this study was phenomenological. Phenomenology is the study of the lived experiences around a specific phenomenon from the point of view of a person or group of people (Christensen, Johnson & Turner, 2010). According to Creswell (2018), a phenomenological study has the following features: (a) an emphasis on a phenomenon, (b) a group identified that experienced the phenomenon, (c) a disclosure of personal biases of the phenomenon by the researcher, (d) interviews with individuals who have each experienced the phenomenon, (e) a data analysis outlining what the participants experienced and how they experienced it, and (f) a final synthesis of the data that describes the participants' experiences.

A phenomenological approach was the most appropriate method to gain knowledge about the best practices to increase students' interest in STEM subjects, which ultimately would increase career and degree participation in STEM-related fields. Specifically, the researcher was able to understand the lived experiences of successful STEM teachers through semi-structured interviews. After interviewing all participants, the researcher transcribed the responses and highlighted significant statements to create common themes (Moustakas, 1994). The researcher then used the themes to describe participant experiences when teaching STEM subjects and how their setting may have influenced their experiences (Creswell, 2018).

Structured process of phenomenology. Moustakas (1994) identified several detailed procedural steps in conducting a phenomenological study, which Creswell (2018) further summarized. The first step is to verify that the research problem is best suited with a phenomenological approach. According to Giorgi (2009), a phenomenological approach is appropriate when the researcher seeks to deeply understand several individuals' experiences of a phenomenon. Second, the researcher identifies the shared phenomenon the participants experienced and attempts to describe it. Third, the researcher attempts to distinguish the philosophical assumptions of phenomenology. To fully achieve this, the researcher must bracket out their own experiences and biases of the phenomenon. Next, the researcher collects data from individuals who have experienced the phenomenon. The most common approach to collect data in a phenomenological study is through in-depth, open-ended interviews (Moustakas, 1994; van

Manen, 1990). The researcher then generates themes from the data by highlighting significant, recurring statements. These themes should provide readers with an understanding of the participants' perspectives of their experiences. After generating themes, the researcher writes a description that includes (a) what the participants experienced, (b) the setting that influenced their experiences, and (c) their personal experiences. From these descriptions, the researcher then reports the "essence of the phenomenon" (Creswell, 2018, p. 80), which focuses on the common experiences of the individuals. Lastly, the researcher presents the findings in written form.

Appropriateness of phenomenology methodology. As mentioned previously, a phenomenological study is an appropriate approach when attempting to understand the collective meaning for a group of individuals of their lived experiences of a phenomenon (Creswell, 2018). More specifically, according to McMillian and Schumacher (2010), the goal of phenomenology is to "transform lived experience into a description of its essence, allowing for reflection and analysis" (p. 24). Since the goal of this study was to explore a phenomenon with several teachers who had all similar experiences, the researcher determined that a phenomenological approach was best suited for this study. Furthermore, through open-ended interview questions, the researcher was able to understand and document the lived experiences of STEM teachers and the best practices, strategies, and challenges they encountered when attempting to increase student interest in STEM subjects. Consequently, the researcher was able to describe what the teachers experienced and how they experienced it (Moustakas, 1994). Exploring teachers' perspectives was crucial to understanding how to increase student interest in STEM subjects, improve academic success, encourage students to pursue a career in STEM, and prepare students with the skills needed to succeed in the 21st-century workforce.

While a phenomenological approach was deemed most suitable for this study, this approach poses several challenges necessary to disclose. First, phenomenology requires the researcher to identify the broad philosophical assumptions associated with phenomenology, which is typically not easily seen in the written study (Creswell, 2018). Second, the researcher may face challenges with identifying and choosing individuals who have all experienced the phenomenon (Creswell, 2018). Third, it is challenging to prevent researcher bias in phenomenological studies. More specifically, since the researcher most likely also has had personal experiences with the phenomenon, they may unintentionally incorporate their assumptions as they interpret the data (Creswell, 2018; van Manen, 1990). This study diminished these challenges through several approaches. First, as mentioned previously, the researcher discussed the philosophical assumptions and frameworks that influenced the research. Second, the researcher identified and explained all personal biases, which is further discussed in this chapter. Lastly, as mentioned later in this chapter, the researcher bracketed personal experiences as a STEM educator, in hopes to not interfere with her interpretation of the data.

Research Design

The following section discusses the research design of this study, including data collection, analysis, interpretation, and report writing (Bogdan & Taylor, 1975).

Analysis unit. The unit of analysis of this research study was a K-12 teacher that taught science, technology, engineering, mathematics, or an integrated STEM-related subject. Creswell and Plano Clark (2011) advocate the importance of selecting individuals that are particularly knowledgeable about and experienced with the phenomenon under study. Therefore, the unit of analysis in this study is a K-12 STEM teacher who is currently a STEM teacher or has previously held the title of a STEM teacher in a school with a top-performing STEM program.

Population. To portray and provide a universal description of the phenomenon more accurately, Grossoehme (2014) suggests gathering detailed descriptions from individuals who have experienced the phenomenon. Therefore, the population in this study included participants who had directly experienced the phenomenon of increasing student interest in STEM subjects.

Sample size. Deciding on the number of participants to include in a qualitative study is an important decision in the data collection process. In a phenomenological study, relatively small sample sizes are required to accurately portray the phenomenon under study (Grossoehme, 2014). Furthermore, Creswell (2018) suggests including a small number of participants while collecting extensive details about each individual involved in the study. However, scholars have differing opinions on how small the sample size should be in a phenomenological study. For instance, in order to effectively explore the phenomenon with all participants, Creswell (2008) recommends that the sample size in a phenomenological study be between five and 25 participants, while Dukes (1984) recommends that it be between three to 10 participants. More so, Morse (1994) suggests having at least six participants, and possibly a maximum of 10, since the researcher will have a large amount of data for each participant. Lastly, when Guetterman (2015) analyzed 11 phenomenological studies in education, he found that the mean sample size at a single site was 15 and ranged from eight to 31 participants.

While there are varying views on the most appropriate sample size, the majority of the literature suggests selecting a smaller sample size to avoid saturation and to allow for a more in-depth exploration per participant (Creswell, 2008; Guetterman, 2015; Morse, 1994). Therefore, based on a synthesis of the above recommendations, the researcher chose to have a sample size of 15 participants to ensure saturation will be reached in the coding and analysis process.

Purposive sampling. The likelihood of gathering in-depth descriptions of lived experiences from participants can be enhanced by using a purposeful sample (Grossoehme, 2014). Purposeful sampling is a strategy used to intentionally sample a group of people that are knowledgeable and have direct experience with the phenomenon being examined (Creswell, 2018; Patton, 2002). Creswell (2018) explains how this strategy requires for the researcher to select individuals and sites for a study because they can "purposefully inform an understanding of the research problem and central phenomenon in the study" (p. 158). More so, the participants must be (a) willing to participate in the study, and (b) able to communicate their experiences in a reflective matter (Bernard, 2002).

Participant selection. To identify and select the individuals who met the criteria to participate in this study, the researcher utilized a screening process that involved (a) creating a master list of all individuals who met the criteria, (b) creating criteria for inclusion and exclusion to further reduce the number of qualified participants, and (c) implementing criteria for maximum variation.

Sampling frame to create the master list. The following steps were taken to reach K-12 teachers experienced with successfully increasing student interest in STEM subjects:

1. A Google (https://www.google.com) search was performed using the terms "best STEM teachers in the Los Angeles area".
2. Once the results were generated, the most accurate result was found on Niche (Niche.com) that listed the results for "2020 best schools for STEM in the Los Angeles area". This list was available to the public (https://www.niche.com).
3. The list ranked all schools in the Los Angeles area based on their STEM programs. Each school also had multiple individuals who met the criteria to be involved in the study. For

instance, the school that ranked number one in STEM had 30 teachers listed in the "mathematics" department and 28 teachers in the "science" department.

4. While the initial site on Niche did not list a directory of teachers or contact information, both were found by directly clicking on the link to the school's website.
5. The researcher created a master list of all STEM teachers from the top 10 schools ranked under "2020 best schools for STEM in the Los Angeles area".

Criteria of inclusion. After generating a master list, the researcher employed the criteria of inclusion to narrow the number of participants further. Specifically, participants in this study were required to meet the following criteria: (a) an expert in their field with at least 3 years of teaching experience in their respective subject, (b) a graduate degree in education or in their respective subject, and (c) current employment in one of the top 10 schools listed under "2020 best STEM schools in the Los Angeles area".

Criteria of exclusion. The following criteria excluded an individual from participating in this study: (a) a participant not willing to have the interview audio-recorded, (b) a participant not available to meet in-person or virtually between January and March of 2020 for a 60-minute interview, and (c) a participant not with8in a one-hour driving proximity from the researcher.

***Purposive sampling maximum variation*.** The final step in selecting participants for this study was based on a sampling strategy called maximum variation. According to Creswell (2018), maximum variation sampling is a popular approach in qualitative studies that involves "determining in advance some criteria that differentiate the participants and then selecting participants that are quite different on the criteria" (p. 158). To increase the representation of diverse backgrounds, the researcher examined the participants' employment position, education level, and geographic location. More specifically, the researcher ensured to select participants from (a) multiple schools, (b) genders, and (c) ethnic backgrounds. As a result, by utilizing the processes of inclusion, exclusion, and maximum variation, the researcher generated a final list of 15 prospective participants.

Protection of Human Subjects

This research study was in accordance with Pepperdine University's Internal Review Board (IRB), which mandates that investigators obtain consent when conducting research with human participants. The following steps were taken to address any ethical concerns and protect human subjects. First, prior to recruiting participants, the researcher obtained an IRB approval application (Appendix A) for review and approval of the study. The application also contained an Informed Consent form (Appendix B) that concealed the protection of their human rights. Selected participants then received a recruitment form (Appendix C) via e-mail inviting them to participate in the study.

Individuals who agreed to participate were reminded that their participation was voluntary, their confidentiality would be secured, and no negative consequences would result from their participation. Throughout the study, confidentiality was guaranteed by utilizing pseudonyms instead of the participants' names and schools' names. While the researcher could not ensure anonymity, identities were not included in the final draft of this study. More specifically, participants were referred to as P1 through P15, resulting in no records that could personally identify any individual. The researcher stored all data in a secure database protected by a password that was only accessible by the researcher. Once the researcher transcribed the interviews, the recordings were destroyed, along with any personally identifiable information. The data that were not destroyed, including transcriptions and all other non-identifiable data, were kept in a secure location and destroyed after 3 years. Lastly, the researcher offered no extrinsic rewards for the participants. Instead, participants benefited from sharing their expertise and experiences that would contribute to STEM fields and the 21st-century workforce.

Data Collection

The researcher collected data for this research study through semi-structured, open-ended interview questions. This method allowed the participants to share their opinions and truthful perspectives of their lived experiences (Creswell, 2008). The researcher contacted the participants via email using the pre-approved recruitment form mentioned previously (Appendix C). Once individuals indicated interest in participating in the study, the researcher emailed them the pre-approved consent form (Appendix B) as well as the pre-approved interview questions (Appendix D). By signing the informed consent form, the participants agreed to participate in a one-hour interview that the researcher would audio record. Once the researcher obtained consent, one-hour interviews were scheduled, either to take place in-person at the participant's place of work, or via the Zoom Conferencing Tool (https://zoom.us). The researcher collected the signed consent form prior to interviewing the subjects, either electronically or in-person. The researcher recorded each interview using two devices and had a printed copy of the open-ended questions, which she used to write notes or reflecting thoughts. By the end of the study, the researcher had conducted interviews with 15 STEM educators. To collect the data, the researcher transcribed the recordings from each interview into a paper copy. The use of semi-structured interviews with open-ended interview questions allowed for the researcher to have a comprehensive view of the participants' lived experiences.

Interview Techniques

There are three types of interview techniques used in qualitative research that the researcher considered. According to Patton (2002), the three interview approaches are: informal or unstructured, semi-structured, and full or structured. Unstructured interviews resemble conversations that are controlled and skewed towards the interest of the researcher (Gray, 2013). Additionally, interview questions in unstructured interviews are unplanned and are typically generated by the interviewer spontaneously during the interview. Although unstructured interviews may yield authentic, comprehensive responses, responses may also be unexpected and different among each interviewee, making it difficult to compare and analyze responses (Kvale, 1996).

In contrast, semi-structured interviews have predetermined, open-ended questions that allow for in-depth responses (Corbin & Strauss, 2008). These core interview questions, also called interview guides, allow for optimum use of interview time by keeping the interview focused on the desired results (DiCicco-Bloom & Crabtree, 2006). Semi-structured interviews also allow for flexibility and creativity from the interviewer, such that the interviewer may pursue a more in-depth response from a particular area that may emerge during an interview, to ensure that each participant's experience is fully revealed (Hill, Thompson, & Williams, 1997).

Lastly, fully structured, standardized interviews allow for each participant to be exposed to the same interview experience (Fontana & Frey, 2005). These interviews are highly structured and consist of closed, definitive questions that may seek "yes" or "no" responses. While structured interviews may provide uniform experiences and responses, it is generally not successful in uncovering participant's lived experiences (Fontana & Frey, 2005).

As mentioned previously, the researcher decided that a semi-structured, in-person interview was most appropriate for this study, as it allows for in-depth, intricate responses to understand the best practices to increase student interest in STEM subjects (Creswell, 2008). The semi-structured interviews also allowed the researcher to identify emerging themes surrounding the challenges that STEM teachers face when trying to increase student interest in STEM subjects and careers. One week before the scheduled interview, the researcher sent the participants a reminder email confirming the meeting day and time, as well as another copy of the interview questions.

The researcher arrived 20 minutes before the meeting time with two recording devices, a clipboard with printed copies of the interview questions, and a pen. In order to build trust and rapport with the interviewee, the researcher began each interview by introducing herself and expressing gratitude for the participant’s time and willingness to partake in the study. Leech (2002) recommends for the interviewer to appear knowledgeable, but also humble to not pose as more of an expert than the interviewee. While they were settling into their seats, the researcher also asked each participant about their day. Before beginning, she collected the signed informed consent form and reviewed the main points highlighted in the form, including a reminder that the interview would be audio recorded. The researcher also reminded each participant that the interview was semi-structured, meaning the interviewer may ask follow-up questions, in addition to the list of questions previously provided, to gain further clarity from the responses. She began each interview once she confirmed that there were no further questions.

The researcher began every interview with two ice-breaker questions about the participant's professional background and general thoughts on student interest in STEM subjects. The researcher then proceeded to ask all 12 questions as well as appropriate follow-up questions. Due to the extensive review of the literature the researcher conducted prior to the interviews, she was able to respond thoroughly and extrapolate themes during the interviews. The researcher also ensured to utilize active listening skills during each interview. Specifically, she focused on the participants’ responses and restated what was in the respondent's language to reassure the participant that she was interested in and understood his/her responses (Adams, 2015). Additionally, as recommended by Adams (2015), the researcher maintained a nonreactive demeanor throughout each interview, neither debating or contradicting the participant. Lastly, the researcher ensured to allow for the interviewees to finish their responses before asking any follow-up or clarifying questions, such as:

- "Can you elaborate on what you mean by…?"
- "Why do you think that is the case…?"
- "Can you tell me more about your experiences with…?"
- "Do you have specific examples of…?"
- "What would you use that for…?"

After asking all of the listed interview and follow-up questions, the researcher asked the interviewee if they had any final thoughts to add or had any questions about the study. Once the researcher addressed all questions, she notified the participant that they could contact her for any questions that may arise. Lastly, to conclude the interview, she thanked each participant for their time. This section provided an overview of the study's interview techniques, as reviewed by the preliminary review committee and approved and finalized by the dissertation committee. Since the protocol was designed for one-time usage, traditional methods of establishing the reliability of the data collection process were not applicable.

Interview Protocol

Data collection in phenomenological studies most often involves interviewing individuals who have experienced the phenomenon under study (Creswell, 2018). Brinkmann and Kvale (2015) recommend designing an interview protocol, or an interview guide, consisting of several open-ended questions to lead the interview. For this study, the researcher developed 12 interview questions from a thorough review of the available literature on student interest in STEM subjects. The researcher gave careful attention to design the protocol questions such that they would be collectively and mutually exclusive. The following interview questions guided the interview protocol:

- IQ1: What pedagogies do you rely on when teaching your subject?
- IQ2: What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students?
- IQ3: How do you feel your academic background and professional training have prepared you to teach your subject?
- IQ4: What is the most challenging part of teaching to students with little interest in STEM subjects, and how does it affect your teaching?
- IQ5: Are there tools or resources are available or can be made available to help you overcome these challenges?
- IQ6: Does teaching students of varying diverse backgrounds, including ethnically diverse and those from a low SES community, pose unique challenges for you. If so, how?
- IQ7: What is your ultimate goal while teaching STEM subjects?
- IQ8: How do you measure the success of your teaching practices?
- IQ9: What behaviors do you believe indicate an increased interest in the subject matter?
- IQ10: What recommendations do you have for novice teachers to succeed in teaching students that are not interested in STEM subjects?
- IQ11: What can academic leaders do differently to better support STEM teachers?
- IQ12: Is there anything else you would like to add?

Relationship between research and interview questions. Table 1 shows the relationship between each research question and the corresponding interview questions. As mentioned previously, the interview questions were inspired and constructed from a review of literature, personal experiences, and a three-step process to ensure validity, which will be discussed in the subsequent sections. Furthermore, the researcher designed each question with the intent to gather an understanding of the collective experiences of the participants who experienced the phenomenon under study.

Validity of the study. According to Creswell (2018), validation in a qualitative research study is the "attempt to assess the accuracy of the findings, as best described by the researcher, the participants, and the readers (or viewers)" (p. 259). Furthermore, the validity of the instrument must be established to ensure that the interview questions adequately address the constructs in the research questions. In this study, the researcher established validity and ensured the interview protocol addressed the research questions through a three-step process that included: prima-facie validity, peer-review validity, and expert-review validity.

Prima-facie validity. *Prima-facie* is Latin in origin and translates to "at first sight" (Herlitz, 1994, p. 392). It is a term often used in law when referring to a case that has enough evidence to be presumed valid (Herlitz, 1994). The four research questions developed by the researcher were reviewed and approved by the dissertation committee to establish the face validity of the instrument and determine whether the instrument accurately assessed the phenomenon under study. The researcher then completed a comprehensive review of the available literature on student interest in STEM subjects, as presented in Chapter 2, to guide her development of the 12 interview questions that were expected to produce thorough responses to each research question. Since each interview question corresponded to one research question, there was face validity in the instrument (Table 1).

Table 1.

Research Questions and Corresponding Interview Question.

Research Questions	**Corresponding Interview Questions**
RQ1: What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?	Icebreaker Q1: Can you tell me a little about your academic background and work experiences? Icebreaker Q2: Do you feel like your students are interested in the subject you teach? IQ 1: What pedagogies do you rely on when teaching your subject? IQ 2: What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students?
RQ 2: What challenges do K-12 teachers face in increasing student interest in STEM subjects?	IQ 3: What challenges do you face when teaching students with little interest in STEM subjects? IQ 4: Do you notice a difference when teaching students of minority groups? IQ 5: What tools or resources are available or can be made available to help you overcome these challenges? IQ 6: To what extent have these challenges impacted your career path?
RQ3: How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?	IQ 7: What is your ultimate goal while teaching STEM subjects? IQ 8: How do you measure the success of your teaching practices?
RQ4: What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?	IQ 9: How can novice teachers succeed in teaching STEM subjects to students with low STEM interest? IQ 10: What can leaders do differently to better support novice STEM teachers? IQ 11: Is there anything else you would like to add?

Note. The table identifies four research questions and corresponding interview questions. Interview questions were later reviewed by a panel of two peer-reviewers and expert reviewers.

Peer-review validity. To provide an objective examination of the accuracy in the researcher's process, scholars advocate the use of an external consultant, such as a peer, who is uninvolved with the research study (Creswell & Miller, 2000; Merriam & Tisdell, 2015; Miles & Huberman, 1994). More specifically, Lincoln and Guba (1985) recommend involving colleagues and students as the reviewers in these peer debriefing sessions. Therefore, the second step to ensure the validity of the instrument involved a peer-review of the interview protocol. More specifically, Table 1 was reviewed by a preliminary panel consisting of two researchers who are currently doctoral students in the Doctor of Education in Organizational Leadership program at Pepperdine University. During the time of review, the students were conducting research and employing a similar research methodology in their own dissertations. Furthermore, the panel members had all completed a series of doctoral-level courses in quantitative and qualitative research methods and data analysis.

To begin the peer-validity process, each peer-reviewer was provided with a paper hard copy of the Peer Review Form (which lists the four research questions with its corresponding interview questions), a summary statement of the research paper, and instructions to follow to accurately assess if the interview questions adequately addressed the research questions (Appendix D). The reviewers made their recommendations by writing directly on the Peer Review Form. When the reviewers completed editing the form, they had a meeting with the researcher to verbally discuss their suggestions and provide the researcher with any clarifications she needed. Table 2 shows the revised interview questions completed after the peer-review validity process.

Table 2.

Research Questions and Corresponding Interview Questions (Revised)

Research Questions	Corresponding Interview Questions
RQ1: What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?	Icebreaker Q1: Can you tell me a little about your academic background and work experiences? Icebreaker Q2: Do you feel like your students are interested in the subject you teach? IQ 1: What pedagogies do you rely on when teaching your subject? IQ 2: What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students? IQ 3: How do you feel your academic background and professional training have prepared you to teach your subject?
RQ 2: What challenges do K-12 teachers face in increasing student interest in STEM subjects?	IQ 4: What is the most challenging part of teaching to students with little interest in STEM subjects, and how does it affect your teaching? IQ 5: Are there tools or resources are available or can be made available to help you overcome these challenges? IQ 6: Does teaching students of varying diverse backgrounds, including ethnically diverse and those from a low SES community, pose unique challenges for you. If so, how?
RQ3: How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?	IQ 7: What is your ultimate goal while teaching STEM subjects? IQ 8: How do you measure the success of your teaching practices? IQ 9: What behaviors do you believe indicate an increased interest in the subject matter?
RQ4: What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?	IQ 10: What recommendations do you have for novice teachers to succeed in teaching students that are not interested in STEM subjects? IQ 11: What can academic leaders do differently to better support STEM teachers? IQ 12: Is there anything else you would like to add?

Note. The table identifies four research questions and corresponding interview questions with revisions based on feedback from peer-reviewers and an expert reviewer. Subsequent changes were made to the order and phrasing of questions within the interview protocol.

Expert review validity. The results from the preliminary review panel were then presented to the dissertation review committee consisting of three faculty members. The dissertation committee then examined and modified the recommendations from the preliminary review panel. The dissertation committee provided an additional layer of validity by sharing their expertise in excellence and innovation practices as it relates to student interest in STEM subjects. In instances where a majority did not agree on a recommended modification, the committee chair had the final vote. Appendix E shows the final list of interview questions.

Reliability of the study. Once the researcher completed the three steps to ensure validity of the instrument, she conducted a pilot interview with an individual who would have met the criteria of a participant. Conducting a pilot interview allowed the researcher to establish the reliability of the instrument. According to Richards and Morse (2012), a study is considered reliable if it can yield the same results if repeated, or if the outcomes of the study show consistency. To establish reliability and consistency of the study, the researcher sought input from the interviewee concerning the clarity of the wording and understandability of the interview questions. The researcher also used feedback from the pilot interview to assess any present biases, reframe questions, and refine data collection procedures (Creswell, 2018).

Statement of Personal Bias

To best understand the experiences of the participants in a phenomenological study, the researcher must set aside any preconceived experiences or understandings of the phenomenon (Moustakas, 1994). The researcher's professional experience in STEM instruction, teaching, and curriculum development have collectively shaped her perspective on the best teaching practices in STEM subjects. Therefore, since the researcher's experiences likely affected the research design, it was important for her to bracket personal biases.

Bracketing and epoche. The acknowledgment of personal existing biases is called bracketing, or epoche. Creswell (2018) recommends for the researcher to bracket themselves out of a study by discussing any personal experiences with the phenomenon. Furthermore, bracketing may allow the researcher to focus on the experiences of the participants without bringing themselves into the study. In this study, the researcher used several bracketing techniques to reduce personal bias. For instance, before interviewing participants, the researcher listed all preconceived thoughts on student attitudes toward STEM subjects and any personal strategies she has used to increase student interest in STEM subjects. The researcher continued to write in this bracketing journal throughout all steps of the research process, reflecting on her thoughts, perceptions, observations, and assumptions. Additionally, during the data collection process, the researcher engaged with outside sources to remove further biases.

Data Analysis

To analyze the data, the researcher used the data analysis-spiral suggested by Creswell (2012). Creswell's approach to analyzing data includes the following steps: (a) manage and organize the data, (b) read and memo emerging ideas, (c) classify codes into themes, (d) develop and assess interpretations, (e) represent the data using visualizations, and (f) provide a summary of the findings. To begin the data analysis process, the researcher first organized the data by electronically transcribing the recorded interviews and storing them in a secure online database.

Reading and memoing. After organizing the data, the researcher proceeded to read the transcripts and memoed developing ideas among participants. Memoing was organized and prioritized throughout the entire analytic process, beginning from the initial read of the database and continuing to the conclusions. According to Janesick (2011), memoing throughout the data analysis process lends credibility to the data. Next, as suggested by Creswell (2018), the researcher continued to immerse herself in the database, reviewing the memos and field notes several times to get a sense of the whole database. After extensively reading and memoing the interview transcripts, the researcher began the process of developing themes to interpret the data.

Coding. The next step involved describing, classifying, and interpreting the data by forming codes. According to Creswell (2018), in vivo coding is when codes are taken directly from participant responses, and pattern coding is when codes are formed from a word or phrase which captures an action. Using a combination of in vivo and pattern coding, the researcher developed 25-30 descriptive and one-worded codes, as recommended by Creswell (2018). The researcher then classified the codes into 5-7 recurring, general themes based on similarities, and created sub-themes when applicable (Creswell, 2018). As the re-review of the database continued, the researcher expanded and re-organized the list of initial codes. The researcher referred to the extensive memos to capture the emerging themes, including highlights of memorable quotes and summary statements of noteworthy aspects perceived in the data. Lastly, to organize the codes and themes, the researcher created a table grouping each interview question with the appropriate codes and themes for all 15 participants. Additionally, diagrams were created representing the relationships among the emerging concepts.

Interrater reliability and validity. The researcher took several steps to ensure the reliability of the study. In qualitative research, reliability refers to the "stability of responses to multiple coders of data sets" (Creswell, 2018, p. 264). According to Creswell (2014), the researcher can enhance reliability by utilizing multiple coders to analyze the data. Therefore, the researcher selected two "co-raters" to participate in the process of ensuring reliability. The co-raters were doctoral students with experience in qualitative research, and also familiar with the theoretical setting of the study. The researcher ensured interrater reliability and validity of the study through a three-step process:

- Step 1: The researcher individually transcribed and coded data from the first three interviews by identifying recurring themes and categories.

- Step 2: The researcher sent the coding results to the panel of co-raters and asked them to review the transcripts and codes. The co-raters reviewed the material independently before informing the researcher whether they agreed with the coding results or whether modifications were suggested. The codes and themes were modified until the co-raters and researcher arrived at a consensus. An expert review from the dissertation chair was conducted when the co-raters and researcher could not arrive at a consensus.
- Step 3: Using the agreed upon coding strategies and based on the feedback from steps 1 and 2, the researcher proceeded to complete coding and analyzing for the remaining interviews. When completed, the researcher forwarded the results to the co-raters for review. Once the peer-reviewers and researcher gained consensus on the codes, the researcher represented the coding results on bar charts, as represented in Chapter 4.

Chapter Summary

Chapter 3 provided a comprehensive description of the methodology utilized in this study, including the research design and techniques for conducting reliable qualitative research. The researcher also discussed the nature of qualitative research and presented the strengths and weaknesses of qualitative and phenomenological studies. The chapter continued with a rationale for the researcher's decision to utilize a phenomenological design to understand the best practices to increase student interest in STEM subjects. The researcher collected data through semi-structured interviews with participants who had direct experience with the phenomenon under study. The interview questions were developed after an extensive review of the literature, and through a three-step process including prima facie, peer review, and expert review to ensure reliability. The chapter concluded with a description of the steps to data analysis. The research findings are presented in Chapter 4.

Chapter 4: Findings

Introduction

STEM-literacy among individuals is necessary to achieve success in the 21st-century workforce (NRC, 2011). To ensure students are adequately prepared to enter these fields, teachers must be aware of the strategies that promote STEM interest, success, and potentially STEM-degree pursuance (Gardner, 2017). The goal of this qualitative, phenomenological study was to identify best practices teachers utilize to increase student interest in STEM subjects. More specifically, the purpose of this study was to determine the following: (a) the successful strategies and practices K-12 teachers employ to increase student interest in STEM subjects, (b) the challenges K-12 teachers face in increasing student interest in STEM subjects, (c) how K-12 teachers measure the success of their practices in increasing student interest in STEM subjects, and (d) the recommendations K-12 teachers would make for future implementation of strategies in increasing student interest in STEM subjects. To accomplish this task, the researcher developed the following four research questions:

- RQ1: What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?
- RQ2: What challenges do K-12 teachers face in increasing student interest in STEM subjects?
- RQ3: How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?
- RQ4: What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?

To examine the research questions, the researcher posed the following 12 semi-structured, open-ended interview questions to each participant:

- IQ1: What pedagogies do you rely on when teaching your subject?
- IQ2: What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students?
- IQ3: How do you feel your academic background and professional training have prepared you to teach your subject?
- IQ4: What is the most challenging part of teaching to students with little interest in STEM subjects, and how does it affect your teaching?
- IQ5: Are there tools or resources available or can be made available to help you overcome these challenges?
- IQ6: Does teaching students of varying diverse backgrounds, including ethnically diverse and those from a low SES community, pose unique challenges for you? If so, how?
- IQ7: What is your ultimate goal while teaching STEM subjects?
- IQ8: How do you measure the success of your teaching practices?
- IQ9: What behaviors do you believe indicate an increased interest in the subject matter?
- IQ10: What recommendations do you have for novice teachers to succeed in teaching students that are not interested in STEM subjects?
- IQ11: What can academic leaders do differently to better support STEM teachers?
- IQ12: Is there anything else you would like to add?

The results from the interview questions served as the source of data for this study, providing an in-depth understanding of the best practices to increase student interest in STEM subjects. This chapter provides a description of each participant, a detailed discussion of the data collection and analysis processes, and an account of the inter-rater review process. Lastly, the researcher presents the findings from the data collection and analysis processes.

Participants

The researcher identified 68 potential participants through a purposive sampling approach, with the intent to interview 15 participants. Nearly all of the participants met the following criteria of inclusion: (a) an expert in their field with at least 3 years of teaching experience in their respective subject, (b) held a graduate degree in education or their respective subject, and (c) have current employment in one of the top 10 schools listed under “2020 best STEM schools in the Los Angeles area.” Although a criterion of inclusion was a graduate degree, two recruited participants did not have a graduate degree, but were included in the study due to having over ten years of teaching experience in one of the top 10 schools listed under “2020 best STEM schools in the Los Angeles area.”

After interviewing three participants, the researcher began to code the data and continued to code after each interview. After coding and creating themes for the first 12 participants, the results indicated data saturation. Data saturation was apparent by the increased number of common responses and themes agreed upon by the participants. As a result of the data reaching saturation after 12 participants, the dissertation committee agreed that 12 participants was sufficient evidence of saturation. For this reason, the researcher ended the interviews after participant 12. The 12 participants were selected from 6 different schools in Los Angeles and represented students from grades K-12. Furthermore, participants included teachers of integrated STEM classes as well as subject-specific teachers. Table 3 illustrates further details about each participant, including their title and the date the interview took place.

Table 3

Participant Details

Participant	Title/Role	Date interviewed
P1	Science specialist	January 21, 2020
P2	Mathematics teacher	January 23, 2020
P3	Middle school science teacher	January 24, 2020
P4	Upper school math teacher	January 24, 2020
P5	Mathematics teacher	January 26, 2020
P6	STEM Program Co-Head, Computer Science Instructor, Mathematics Instructor	January 27, 2020
P7	STEM teacher	January 31, 2020
P8	STEM Program Co-Head, Science Instructor	January 31, 2020
P9	Science and technology teacher	February 6, 2020
P10	Mathematics department chair and teacher	February 8, 2020
P11	Middle school mathematics teacher	February 11, 2020
P12	Makerspace/robotics teacher	February 12, 2020

Data Collection

The researcher began recruiting participants on January 14th, 2020, after obtaining full IRB approval on January 13th, 2020. In an initial email or message via the social media platform LinkedIn (https://www.linkedin.com), the researcher sent 15 potential participants an invitation to participate in the study, as outlined in the IRB approved recruitment script (Appendix C). A majority of participants did not respond to the initial message. Seven days after the initial message, a second message was sent to the non-responders, which yielded two additional responses. Since only three of the 15 participants expressed interest in participating, the researcher revisited the master list and reached out to an additional 30 participants. This yielded five additional participants. To recruit more individuals, the researcher had to revisit and expand the master list. On January 22nd, 2020, the researcher distributed recruitment emails to 23 new participants, which yielded four additional interviews. Between January 14th and February 12th, a total of 68 recruitment emails were sent, which yielded a total of 12 completed interviews.

Once the K-12 STEM teacher expressed willingness to participate in the study, the researcher and participant exchanged back-and-forth emails to schedule a time and date for the interview. The researcher accommodated participants' schedules and allowed them to choose between an in-person or virtual meeting. Once a meeting day was agreed upon, the researcher sent participants a copy of the informed consent form (Appendix B), which included the interview questions. The researcher addressed any questions participants had before the interviews. On the day of the interview, the researcher reviewed highlights from the informed consent form with each participant and asked if they had any clarifying questions. The researcher also reminded each participant of the processes to ensure confidentiality throughout the study. Once the researcher verified that there were no further questions, she began recording the meeting and proceeded to ask the pre-determined, 12 interview questions.

As mentioned in Chapter 3, the interview questions were open-ended and allowed for follow-up questions. Additionally, the interview questions were designed to identify the participants’ descriptions of their lived experiences of increasing student interest in STEM subjects. While 60 minutes was requested per interview, interview times ranged from 18-70 minutes. Lastly, four of the interviews were conducted in-person at the participants place of work, while the remaining 8 interviews were conducted via the videoconferencing tool, Zoom.

Data Analysis

Participants' interview responses were the primary source of data collection for this phenomenological study. Before analyzing the data, the researcher ensured to bracket her personal biases and thoughts associated with student interest in STEM subjects. Doing so allowed the researcher to interpret the data through an objective lens (Moustakas, 1994).

After the researcher set aside personal and previous assumptions about the phenomenon, she began the data analysis process. As discussed in Chapter 3, the first step in data analysis involved listening to the audio-recordings and transcribing the interviews into a Microsoft Word document. To enhance the credibility of the data, once the transcripts were complete, the researcher read through the interviews and took notes, highlighting keywords and phrases (Janesick, 2011).

After informally analyzing the responses and observing participant responses from the first six interviews, the researcher concluded that IQ6 was not an appropriate question. Since the participants were teachers from affluent private schools, they did not appear to have any experience teaching students from a low SES, as stated in IQ6. Therefore, the researcher and committee members agreed to remove IQ6 for the remaining participants. This will further be addressed in Chapter 5.

Once the interviews were transcribed, the researcher created a shared Google Sheet file, which was organized by the interview questions and participants. The researcher then re-read the transcripts and created codes for each interview question, which was added to the Google spreadsheet. The codes were then analyzed and grouped into 5-7 common, recurring themes. When completed, the spreadsheet included tables grouped by each interview question with the appropriate codes and themes for all 12 participants. The themes were created by utilizing descriptive wording from the transcripts.

Inter-rater review process. After coding and creating themes for the first three interviews, the researcher temporarily concluded the data analysis process and utilized an inter-rater review protocol to ensure validity. The inter-rater review process was performed by two doctoral students enrolled in the Doctor of Education in Organizational Leadership program at Pepperdine University. The doctoral students were selected due to their education in qualitative research and experience with the research methodology.

The panel began by discussing the researcher's general data analysis process. The researcher then shared the working spreadsheet of the coded data, a copy of the interview questions, and the interview transcripts with both doctoral students. The doctoral students analyzed the interpretation of the data and provided feedback and recommendations directly on the working document. After the researcher viewed the recommendations, she had a follow-up discussion with the doctoral students to assist with any clarifying questions. Most of the suggestions regarded minimizing the number of themes and rewording theme names. The researcher and doctoral students discussed the recommendations until they reached a consensus. If a consensus could not be reached, the researcher consulted expert review with the dissertation committee. After utilizing this process for the first three interviews, the researcher proceeded to code and create themes for the remaining interviews. The inter-rater review process was then repeated for the remaining nine interviews.

Data Display

The data in this study are organized and presented by a research question and the corresponding interview questions. Common phrases, viewpoints, and responses are grouped together for each research question. Each interview question is accompanied by a frequency chart to provide a visual representation of the results. Furthermore, below each frequency chart is a description of each theme, accompanied with quotes directly from participants. To preserve the integrity of the data, statements are reported verbatim and may include incomplete sentences and conversational language. The researcher also references the interviewees in order, with the first interviewee labeled as P1, the second interviewee as P2, and so on through P12. Doing so allowed the researcher to ensure that the participants' intent is clearly communicated while maintaining anonymity.

Research Question 1

The first research question (RQ1) asked, What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects? The researcher asked a total of three interview questions to the participants in order to answer RQ1. The following three questions related to RQ 1:

1. What pedagogies do you rely on when teaching your subject?
2. What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students?
3. How do you feel your academic background and professional training have prepared you to teach your subject?

To understand the strategies and practices K-12 teachers employ to increase student interest in STEM subjects, the researcher analyzed the responses from the participating teachers and identified recurring themes and similarities in their responses.

Interview question 1. IQ1 asked, What pedagogies do you rely on when teaching your subject? After an analysis of all interview responses to IQ1, a total of 27 responses related to pedagogies used while teaching STEM subjects. The responses were grouped into four corresponding themes. The themes that emerged were: (a) active learning, (b) facilitated learning, (c) social constructivist, and (d) differentiated learning (see Figure 1).

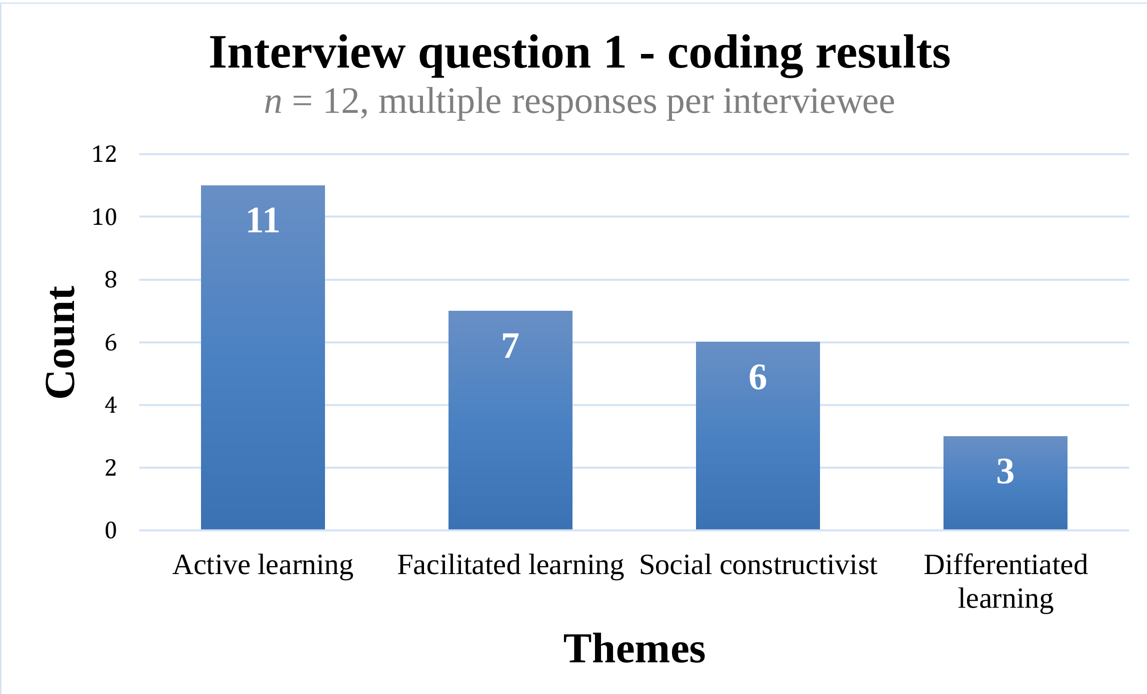

Figure 1. The most common practices employed by teachers in STEM classrooms. This figure demonstrates the four themes that emerged from the responses to IQ1. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made statements that fell into the respective theme.

Active learning. Active learning is a form of teaching pedagogy that maximizes individual and collaborative learning through activities and classroom discussions (Handelsman et al., 2007; D. W. Johnson et al., 1998). Of the 27 phrases, viewpoints, or responses, 11 (41%) of the responses to IQ1 related to active learning pedagogies, representing 92% of participants. The responses that related to active learning included the following phrases: inquiry learning, hands-on approaches, open-ended assignments, project-based learning, problem-based learning, collaborative learning, exploratory assignments, investigative work, engaging students in the process, and presenting activities before concepts. For instance, P4 shared, “I lean more towards problem-based and discovery learning where I try to make problems and see what students can make from it and have them explain the concepts." Furthermore, P3 stated, "I always incorporate hands-on projects where they can create something."

Facilitated learning. The second most common pedagogy identified by the responses was facilitated learning. Of the 27 phrases, viewpoints, or responses to IQ1, seven (26%) of the responses related to facilitated learning. The theme of facilitated learning included keywords such as: guided notebooks, independent work, and guided-note taking. For instance, P9 illustrated the importance of being the "guide on the side", while P5 elaborated on the idea of providing students guided notes to allow students to "explore and discover what we're trying to learn." Lastly, P1 said, "They [students] are generating their own ideas and I'm just the facilitator of their discussions and learning, there to help them understand our learning targets."

Social constructivist. The third most notable pedagogy identified by the participants was social constructivism. A social constructivist view on learning states that students learn best through social and cultural interactions and when they are actively engaged in the learning process (Ertmer & Newby, 2013). Of the 27 phrases, viewpoints, or responses, six (22%) were related to social constructivism. Responses for this theme included promoting partner discussions, group work, and back and forth dialogue. P12 elaborated on this theme, stating, "I have them work in groups to develop a shared understanding of the process and their designs."

Differentiated learning. Applying differentiated learning in STEM classrooms was the final pedagogy noted in response to IQ1. Of the 27 phrases, viewpoints, or responses, three (11%) were related to a differentiated learning pedagogy. The theme of differentiated learning included the following: providing students with different varieties of presentation, multiple methods of assessments, and an effort to reach all types of learners. For instance, P9 stated,

> We often make assumptions about what students may already know so it's important to give them all a common experience. Like if you're talking about waves in physics do not assume all of your students have been to the ocean and know what a wave looks like.

More so, P3 elaborated on the importance of providing students with multiple modalities of assessments, stating, "Some kids can show really well what they can do with a test and some kids can't, so I always have a test and project and weigh them equally." The responses from IQ1 allowed for an understanding of the specific pedagogies K-12 STEM teachers rely on while teaching their subjects.

Interview question 2. Similar to IQ1, IQ2 asked, What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students? This question compelled participants to further reflect on the strategies they utilize to successfully engage students in STEM subjects. IQ2 yielded a total of 32 responses that identified as strategies to increase student interest in STEM subjects, which the researcher grouped into five different themes. The five themes that emerged were as follows: (a) create an authentic classroom environment, (b) create ownership, (c) enrichment activities, (d) instructional variety, and (e) integrate STEM into other disciplines (see Figure 2).

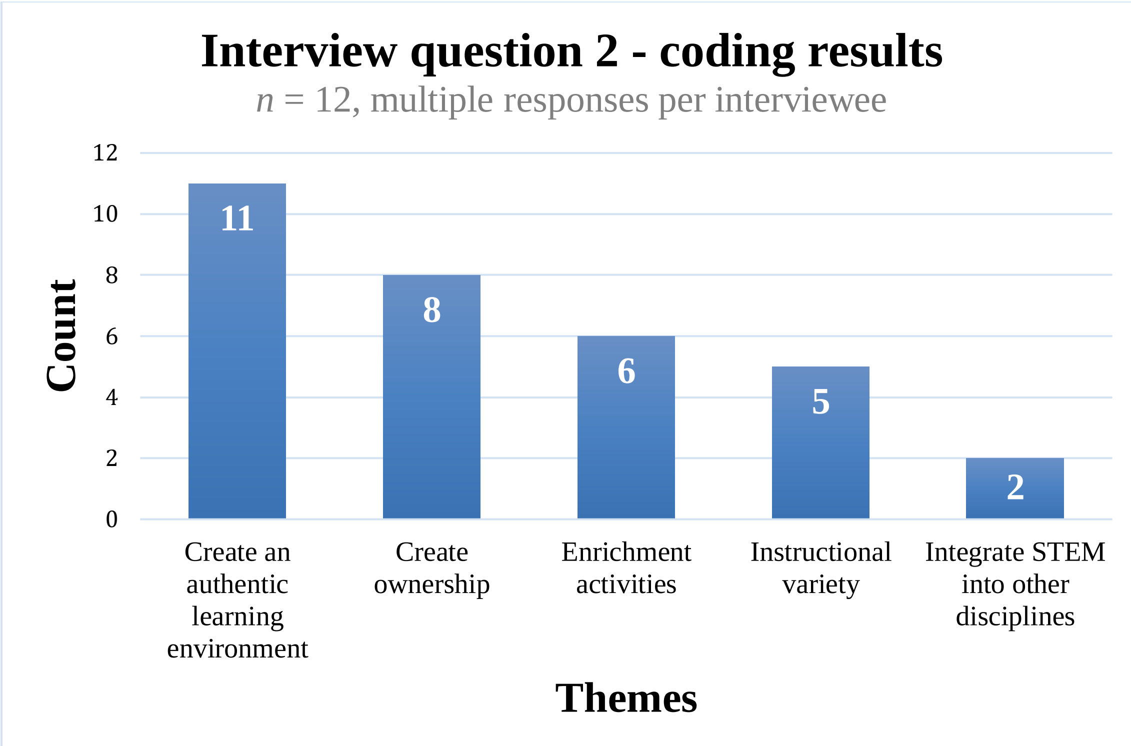

Figure 2. Strategies utilized by teachers to increase student interest in STEM subjects. This figure demonstrates the five themes that emerged from the responses to IQ2. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Create an authentic learning environment. According to participants' responses to IQ2, the most common strategy utilized to increase student interest in STEM subjects was focusing on creating an authentic learning environment. This element was common among 92% of the participants and contributed to eleven (34%) of the responses. Creating an authentic learning environment was associated with the following three sub-themes: creating relationships with students, providing contextualized instruction, and making the subject enjoyable for students. More so, the sub-themes of authentic learning environment included the following phrases, viewpoints, or responses: be relatable to students, build personal relationships with students, welcome all answers, reaffirm their value, provide clear expectations, allow for student feedback, relate concepts to student interests, create meaningful classroom experiences, bring down student defenses, make it a good time, and create a fun environment. P2 advocated the importance of creating relationships with students, stating,

> My strategy is to create a relationship with the kid, then make them feel safe and valued. If I can sort of fool them into having a good time so their defenses go down, then I have a chance to get the material past them. I want them to feel like this is a fun environment to be in and it's fun to be part of these discussions. All these things are important in creating that relationship with the kids and the dynamics of the whole classroom, and I think it's a lot more vital than how I may structure my particular lesson or anything like that.

P4 further recognized the importance of prioritizing student-teacher relationships by stating,

> Teaching for me has always been about the relationship connections with students before the subject. Like it's less about the math and more about the personal relationship there, making it clear to them that I care about them as a person is more important than any strategy.

Creating meaningful experiences for students was also a common strategy to increase interest in STEM subjects, with P8 stating, "I like to connect things to the real-world and create meaningful, culminating experiences for students that will hopefully be remembered." Lastly, participants reported that they try to make the lessons relevant to students, with P12 sharing, "I heavily rely on students' interests and what excites them." To conclude, nearly all participants recognized the importance of creating an authentic learning environment for students, where emphasis is on student-teacher relationships, creating enjoyable experiences, and making learning relevant to the students.

Create ownership. The second theme for IQ2, creating ownership, also addressed the strategies used to increase student interest in STEM subjects. Of the 32 responses, viewpoints, or phrases, eight (25%) of responses to IQ2 were related to creating ownership. Responses associated with creating ownership over learning included the following phrases: making students accountable, allowing students to make decisions, creating opportunities for students to showcase their creations, creating opportunities for creativity, and encouraging students to speak up. For instance, P8 reported, "Giving students opportunities to share what they're creating, whether in a showcase or just in class, giving them a platform to share their work allows them to take ownership over it and makes them more engaged in the content." Likewise, P6 shared a similar strategy, stating, "It gets students motivated when they know they have to show their projects in front of the rest of their class."

Enrichment activities. Participants' responses from IQ2 identified providing students with enrichment materials and activities as the third most common strategy to promote student interest in STEM subjects. Of the 32 phrases, viewpoints, or responses, six (19%) of the responses were related to providing students with enrichment opportunities. All of the participants who spoke about enrichment activities claimed they did so by providing students with challenges or a challenging curriculum. For instance, P1 said,

> I have engineering challenges that relate to the engineering standards. The other day I showed them a demonstration of erosion and told them they get to do this themselves, in order to keep a house from eroding. Afterwards a student came to me and very enthusiastically said that he always looks forward to the engineering challenges.

Furthermore, while P1 emphasized their strategy of creating team problem-solving challenges, P3 further elaborated on this strategy, stating, “I’m all about giving students projects and framing them as challenges they have to solve.”

Instructional variety. The fourth theme ranked in frequency as a strategy to increase student interest in STEM subjects was having a variety or flexibility in instruction. Of the 32 phrases, viewpoints, or responses, five (16%) of the responses to IQ2 were related to using a variety of instructional strategies. The theme of instruction variety included incorporating the following: hands-on experiments, games, group work, open-ended assessments, the use of multiple curriculum resources, and having a variety in activities. P10 stated,

> We don't just rely on one publisher; rather, we pick the resources we feel are best for the students. They are textbooks, activities and problems. We use various activities, such as Kahoots, matching index cards, bingo review days, and using small white boards.

Integrate STEM into other disciplines**.** The final theme ranked in frequency as the fifth most common strategy to increase student interest in STEM subjects was to integrate STEM subjects. Of the 32 phrases, viewpoints, or responses, two (6%) of the responses were related to integrating STEM disciplines. The theme of integrating STEM subjects included relating the discipline to other subjects, both within STEM fields and outside of STEM fields. For instance, P7 proclaimed, “As a school, we’re trying to show the other disciplines like arts and humanities that the engineering process is present in every discipline, like in a history paper or writing assessment.” Through this lens, P7 believes that when students realize they are doing STEM in all subjects, it could increase their interest and motivation in STEM-related disciplines. Similarly, P2 indicated, “I like when they call it STEAM instead of STEM because I like the idea of the arts and the creative aspect being brought into it.”

Interview question 3. IQ3 asked, How do you feel your academic background and professional training have prepared you to teach your subject? Due to the variety of responses to IQ3, the researcher coded the responses which related to the aspect of their academic background and professional training that prepared them best for their role as a STEM teacher. As a result of this question, the researcher was able to identify participants' beliefs on the necessary and valuable requirements of exemplary STEM teachers. IQ3 yielded a total of 18 responses which the researcher grouped into four different themes. The themes that emerged were as follows: (a) lived experiences inside and outside of the classroom, (b) internal drive, (c) content knowledge, and (d) professional development (see Figure 3).

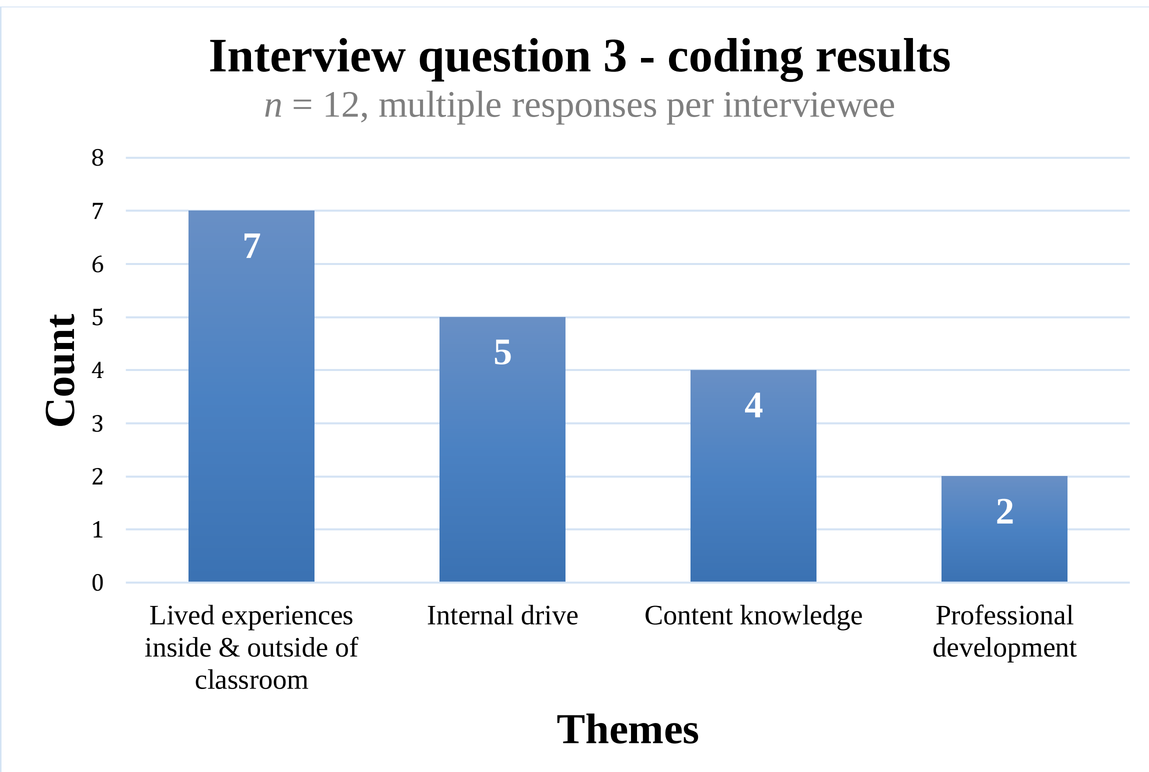

Figure 3. The most valuable aspect of teachers' academic background and professional training that prepared participants best to teach their subject. This figure demonstrates the four common themes that emerged from the responses to IQ3. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Lived experiences inside and outside of the classroom. IQ3 yielded lived experiences inside and outside of the classroom as the most significant aspect of participants' academic background and professional training. Of the 18 phrases, viewpoints, or responses, seven (39%) of the responses collected were related to participants' lived experiences inside and outside of the classroom. That is, experiences that were not part of teacher professional training or academic background. The theme of lived experiences inside and outside of the classroom included the following phrases: classroom management, ability to anticipate questions, anticipation of struggle points, diverse background, application knowledge, knowing how to teach, having a broad skill set, managing complex projects, in-vivo experiences, and applying real world, problem-solving skills. For example, P4 stated, "The ability to anticipate struggle points and being flexible in how you give alternate explanations to those things is crucial, and more important than any amount of content knowledge."

Internal drive. Having an internal drive was the second most common requirement participants identified that prepared them to teach their subject. Of the 18 phrases, viewpoints, or responses, five (28%) of the responses were related to having an internal drive. The theme of internal drive included the following phrases: having a passion for the subject, doing research beyond what is required, motivating the students, and being genuinely interested in the subject. For instance, P11 said, "I think there needs to be an interest by the teacher more than needing a degree in that subject." Meanwhile, P5 noted the challenges she faces with having the content background and academic training, stating,

> I cannot just rely on my professional training and master's degree in education. There's still a lot of research I have to do with every concept. I've found that textbooks

are very dry, and I have to use so many different resources to find something that's real world and engaging for the students.

Lastly, P12 said, "Technology and making things is always something I just did, so having that hobbyist/tinkering background, finding that passion and internal motivation, I think that has really helped me in connecting with the students over design and making."

Content knowledge. Contrary to several responses, having content knowledge from a STEM-related degree was identified as an important aspect of participants' preparedness to teach in STEM-related subjects. Of the 18 phrases, viewpoints, or responses, four (22%) of the responses to IQ3 were related to content knowledge. All of the participants in this theme reported content background and research experience as an important requirement for STEM teachers. More specifically, P6 explained,

> I think content knowledge with coding is really important, and I often see people discounting the amount of content knowledge that is required to do a good job in the classroom. What's also helpful is my diverse academic background. Because of that, I always try to bring math, science, or computer science into whatever I'm doing. So, for me, my academic background in math, science, and visual arts has been very helpful when creating different projects to reflect students' varying interests.

P10 further advocated the need to have strong content knowledge, stating, "To do what we want to do where the students are really understanding math and getting the connections and intricacies, you have to have a teacher who has strong knowledge of the content."

Professional development. The final theme ranked in frequency as the fourth most commonly mentioned aspect of participants' preparedness to teach in their subject was professional development. Of the 18 phrases, viewpoints, or responses, two (11%) of the responses were related to professional development. The theme of professional development included phrases such as: being a lifelong learner, continuing education, and attending professional development or training. For example, P10 advocated the importance of professional development relating to student diversity, stating, “Professional development is super important when it comes to responsive teaching and being able to adjust for that variety in the classroom, that’s not something that comes naturally so you have to train teachers how to do that.” Similarly, P3 said the following:

> I got my degrees a really long time ago and I have learned so much since then as a teacher through professional development. I feel like more than my academic background, my continuing education has been crucial, especially because technology keeps changing and I can’t keep doing the same thing over and over.

Summary of RQ1: Research question 1 sought to identify the strategies and practices teachers employ to increase student interest in STEM subjects. A total of 13 themes were identified by analyzing phrases, viewpoints, or responses to the first three interview questions. Responses to this question identified the pedagogies teachers rely on when teaching STEM subjects, the specific strategies they employ to increase student interest, and the noteworthy experiences that prepared them to teach their subject. The 15 themes identified were as follows: (a) active learning, (b) facilitated learning, (c) social constructivist, (d) differentiated learning, (e) create an authentic learning environment, (f) create ownership, (g) enrichment activities, (h) instructional variety, (i) integrate STEM into other disciplines, (j) lived experiences, (k) internal drive, (l) content knowledge, and lastly (m) professional development.

Research Question 2

The second research question (RQ2) asked, What challenges do K-12 teachers face in increasing student interest in STEM subjects? The researcher asked a total of two interview questions to the participants in order to answer RQ2. The two questions related to RQ2 were:

1. What is the most challenging part of teaching to students with little interest in STEM subjects, and how does it affect your teaching?
2. Are there any tools or resources available or can be made available to help you overcome these challenges?

To understand the challenges K-12 teachers face when attempting to increase student interest in STEM subjects, the researcher analyzed the responses from the two interview questions and identified recurring themes and similarities in their responses.

Interview question 4. IQ4 asked, What is the most challenging part of teaching to students with little interest in STEM subjects, and how does it affect your teaching? After an analysis of all interview responses to IQ4, a total of 22 phrases, viewpoints, or responses related to the challenges encountered when teaching to students with little interest in STEM subjects. The responses were grouped into four different themes. The themes that emerged were as follows: (a) student intrinsic motivation, (b) previous negative STEM experiences, (c) consistent teacher engagement, and (d) differentiation (see Figure 4).

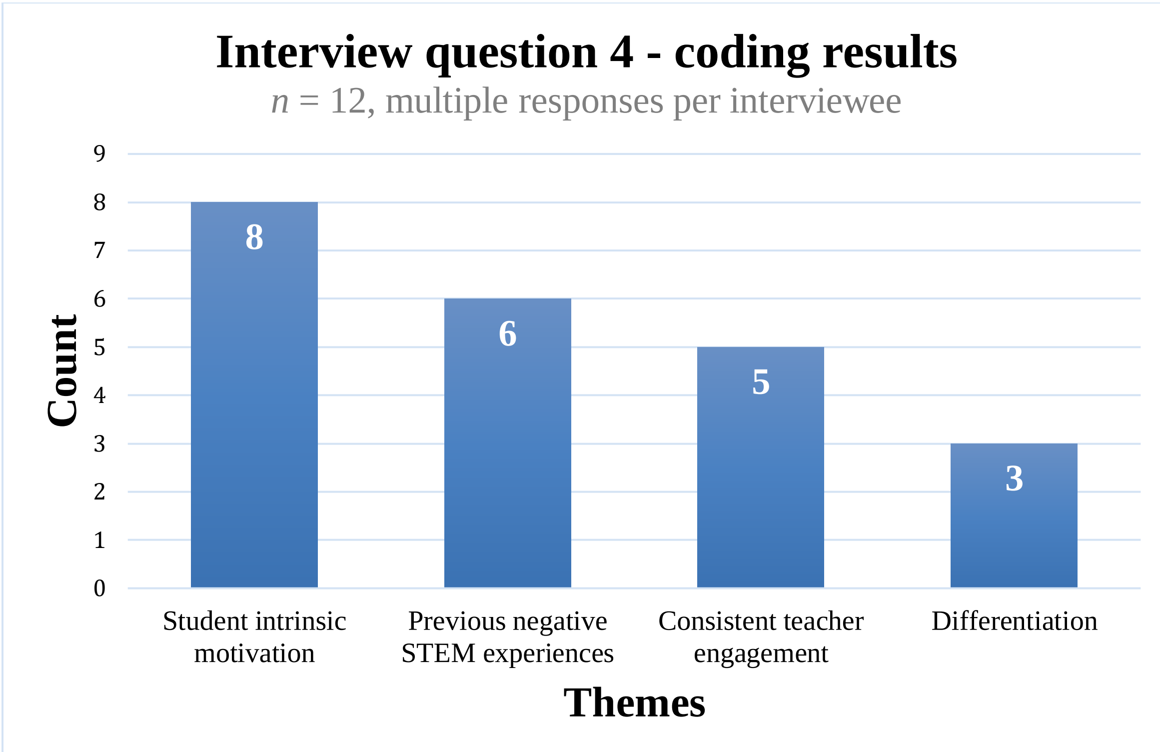

Figure 4. The most notable challenges teachers face when teaching to students of little interest in STEM subjects. This figure demonstrates the four common themes that emerged from the responses to IQ4. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Student intrinsic motivation. IQ4 yielded students' intrinsic motivation as the most notable challenge when teaching to students with little interest in STEM subjects. Of the 22 phrases, viewpoints, or responses, eight (36%) of the responses collected were related to students' intrinsic motivation. The theme of student intrinsic motivation included the following: students not opening up, students who are grade or college focused, students working for parents, students remaining accountable, getting students to tap into their own abilities, disruptive students, students lack of effort, and lack of engagement. P8 made it very evident that this was a challenge, stating, "The most challenging part is having a student who is not intrinsically motivated, they are more likely to give up. Getting students to tap into their own problem-solving ability and become more intrinsically motivated is my greatest challenge." Students being extrinsically motivated was another challenge noted by several participants, with P3 explaining,

> As they get older, they [students] stress about doing the right thing and getting into college. They're not doing AP biology because they necessarily want to, they're doing it because they feel like they should, and I think that's a real hard battle we're facing.

Previous negative STEM experiences. The second most distinguished challenge identified was the previous negative STEM experiences that students carry with them throughout their STEM courses. Of the 22 phrases, viewpoints, or responses, six (27%) of the responses to IQ4 were related to students' previous negative STEM experiences. The theme of previous negative STEM experiences included the following: having students forget prior notions, STEM stress/anxiety, anti-math sentiment, fixed mindset, students overcomplicate subject, student resistance, not identifying as science students, and identifying the reason for their resistance. For example, P9 indicated, "It's a challenge when students are resistant, say that it's not my thing, and then check out. Somewhere along the way they decided that they don't identify as science students." P10 further elaborated on this challenge, stating, "As a teacher there could be these long-lasting issues that get in the way and actually have nothing to do with you and your class, so finding that out is helpful."

Consistent teacher engagement. Consistently engaging students who are not interested in STEM subjects was another notable challenge identified by IQ4. Of the 22 phrases, viewpoints, or responses, five (23%) of the responses to IQ4 were related to the teacher's challenge with consistently engaging the classroom. The code words for consistent engagement included the following: finding the balance between fun and exploration, being able to make quick decisions, being consistent, relating teacher interests with student interests, and feeling discouraged because of the lack of engagement. P4 explained how their personal motivation is sometimes affected by students' lack of interest, stating,

> Students' motivation feeds off to how much I feel capable of doing and giving, and it creates this negative feedback loop if you let it. Like when they're not feeling it so I'm not feeling it which makes me not want to put my all into it and now they're even more not engaged.

P11 shared similar frustrations, saying, "It brings me down when they [students] come into class without doing their work."

Differentiation. Differentiation ranked lowest in frequency for the challenges teachers faced when teaching students with little interest in STEM subjects. Of the 22 phrases, viewpoints, or responses, three (14%) of the responses were related to student differentiation. The theme of differentiation included difficulties with the following: targeting learning to student needs, meeting students where they are, communication, and varying foundations. P2 further discussed the challenge of differentiation, saying, "Everybody in this classroom can do great but everybody doesn't come in with the same foundations. It will all come together if we all have the same effort and push in the same direction."

Interview question 5. IQ5 asked, Are there any tools or resources available or that can be made available to help you overcome these challenges? After an analysis of the responses to IQ5, a total of 17 phrases, viewpoints, or responses related to the tools or resources that can help teachers overcome their challenges. The responses were grouped into four different themes: (a) collegiality, (b) continuing education opportunities, (c) curriculum resources emphasizing application, and (d) administrative support (see Figure 5).

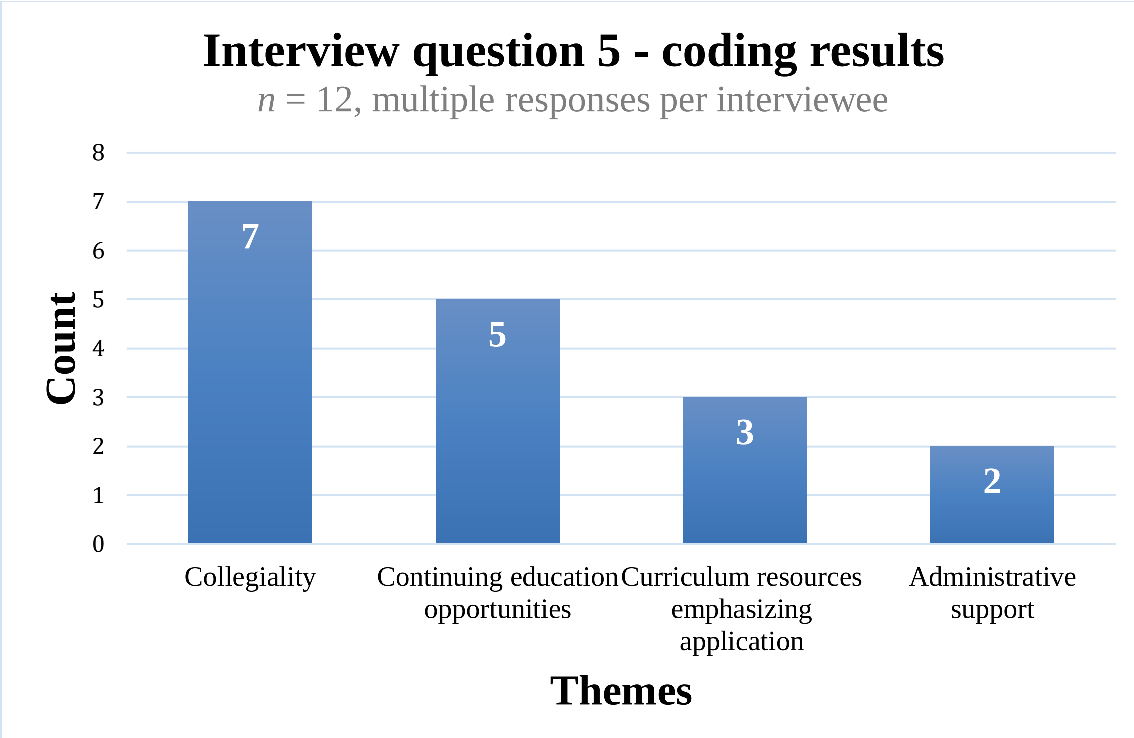

Figure 5. The most notable tools or resources to help teachers overcome challenges. This figure demonstrates the four common themes that emerged from the responses to IQ5. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Collegiality. Collegiality ranked highest in frequency for the resources available or that can be made available to help teachers overcome their challenges. Of the 17 phrases, viewpoints, or responses, seven (41%) were related to collegiality. The theme of collegiality included the following: faculty interactions, technology mentors, makerspace teachers, shared workspaces, communities, online platforms to connect with similar teachers, colleagues from different backgrounds, and additional time with colleagues. For example, P3 explained, “It’s helpful to a go-to person to bounce ideas, like a technology mentor, and help me when I’m trying to enhance my curriculum with new ideas.” P4 further elaborated on the value of collegiality, especially in an informal setting, stating, “Our department shares an office so there’s a lot of informal interaction with peers, where we can sit and talk about ideas, advice, or just about how they taught a particular student. Having that is really important to me.” Lastly, P12 discussed how time with colleagues improved his lessons, sharing, “It would be tremendously helpful to have more time with colleagues because when I’m able to connect with them and spend time brainstorming out topics and lessons, it inevitably improves them.”

Continuing education opportunities. Continuing education opportunities ranked second highest in frequency in response to IQ5. Of the 17 phrases, viewpoints, or responses, five (29%) were related to continuing education opportunities. The theme of continuing education opportunities included: professional development, resources for English learners, growth mindset initiatives, and conferences on student diversity. P5 noted, “I’m always looking for professional development that brings in social justice issues with math.” Additionally, P10 shared, “The conversation about growth mindset, not just for me and my department, but for all teachers is a huge thing. Resources to educate teachers, students, and parents are very helpful.”

Curriculum resources emphasizing application. Access to curriculum resources that emphasize application that have been tested ranked third highest in frequency in response to IQ5. Of the 17 phrases, viewpoints, or responses, three (18%) were related to curriculum resources. The theme of curriculum resources emphasizing applications included the following phrases: access to practiced resources, tried and succeeded curricular resources, access to industry professionals, access to pre-created curriculum programs, and pre-tried activities that apply concepts to the real world. Two examples include the following:

- “It’s nice to have curriculum programs specifically designed for students who don’t see themselves as scientists” (P9).
- “I haven’t found a place where teachers could access industry professionals who are applying these concepts, a place where teachers could gain insight into how real jobs are done with the concepts we learn in the classroom” (P8).

Administrative support. Administrative support ranked lowest in frequency as a resource that would help teachers overcome their challenges. Of the 17 phrases, viewpoints, or responses, two (12%) were related to administrative support. The theme of administrative support included having the flexibility to try new experiments, disciplining students when needed, and communicating with families. For example, P11 said, "It's helpful when the administration is supportive of when students are falling behind, and they can help with contacting families to help students get back on track."

Summary of RQ2. Research question 2 sought to identify the challenges K-12 teachers face when teaching to students with little interest in STEM subjects. A total of eight themes were identified by analyzing phrases, viewpoints, or responses from IQ4 and IQ5. The eight themes identified were the following: (a) student intrinsic motivation, (b) previous negative STEM experiences, (c) consistent teacher engagement, (d) differentiation, (e) collegiality, (f) continuing education opportunities, (g) curriculum resources emphasizing application, and lastly (h) administrative support.

Research Question 3

The third research question (RQ3) asked, How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects? The researcher asked a total of three interview questions to the participants in order to answer RQ3. The three questions related to RQ3 were the following:

1. What is your ultimate goal while teaching STEM subjects?
2. How do you measure the success of your teaching practices?
3. What behaviors do you believe indicate an increased interest in the subject matter?

To understand how K-12 teachers measure the success of their practices, the researcher analyzed the responses from the three interview questions and identified the recurring themes.

Interview question 7. IQ7 asked, What is your ultimate goal while teaching STEM subjects? After an analysis of all interview responses to IQ7, a total of 28 phrases, viewpoints, or responses were identified that related to teachers' ultimate goals while teaching STEM subjects. The responses were grouped into five common themes. The themes that emerged were as follows: (a) instill grit and empower students, (b) make STEM enjoyable, (c) apply skills in real world situations, (d) make students feel valued, and (e) content knowledge (see Figure 6).

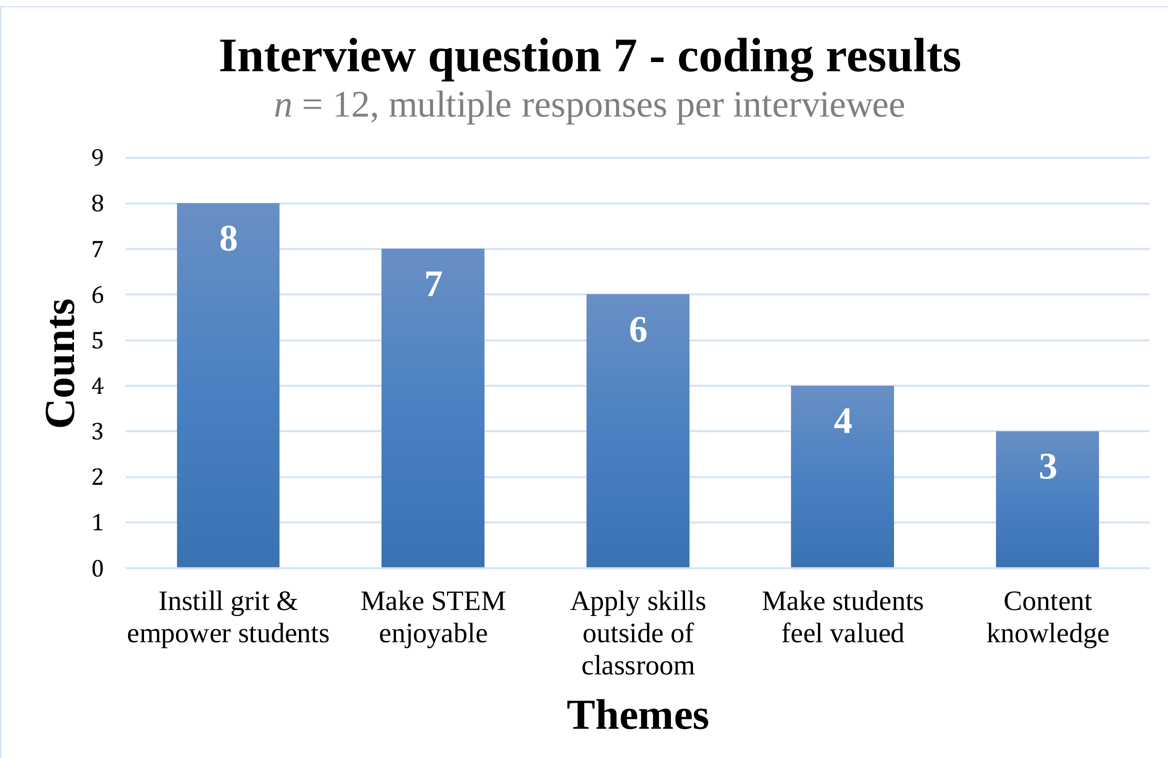

Figure 6. The most notable goals participants have while teaching STEM subjects. This figure demonstrates the five common themes that emerged from the responses to IQ7. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Instill grit and empower students. In response to IQ7, participants' ultimate goal of instilling grit and empowering students ranked as the highest in frequency. Of the 28 phrases, viewpoints, or responses, eight (29%) were related to instilling grit and empowering students.

The theme of instill grit and empower students included the following phrases: engaging girls, being a positive role model, feeling capable, knowing goals are attainable, independent, responsible for learning, empower them to create, feel empowered in STEM, be confident, feel like they can create anything, grit, feel like they can accomplish anything, find comfort in exploring. P9 elaborated on their desire to empower students, stating, "I want them to feel like when they're faced with something new and challenging that they can still do this, and feel like every problem they're going to face in their life is a fixable problem." P8 further explained, "I would like for them to feel empowered to pursue these fields and have the confidence and feel like they can create anything." Similarly, P2 noted, "I want the kids to feel like whatever problem they encounter is not beyond a response", while P12 stated, "My hope is they walk away from my classes feeling like no matter what the topic, I can dive in and try this, with a comfort and willingness to explore."

Make STEM enjoyable. Making STEM and STEM learning enjoyable ranked as the second highest in frequency regarding participants' ultimate goal while teaching STEM subjects. Of the 28 phrases, viewpoints, or responses, seven (25%) were related to making STEM enjoyable. This theme included the following phrases: have a good time, be engaged, break science stereotypes, simplify STEM, spread the joy of math, get them excited, have an appreciation for the subject, not be bored. P1 expressed her desire to make STEM enjoyable, stating, "My number one goal is to create a place where students can have a good time and be engaged in STEM and realize that science, math, engineering, all these subjects can be exciting." Meanwhile, P4 expressed wanting to combat the anti-math sentiment, saying, "I don't need every kid to walk out of here totally in love with math, but spreading the joy in math and learning is important." Lastly, P10 expressed, "I want to show them that math is not boring, and although it can be challenging, there can be interest and fun in a challenging subject."

Apply skills outside of the classroom. Applying learned skills outside of the classroom ranked as the third highest in frequency regarding participants' ultimate goal while teaching STEM subjects. Of the 28 phrases, viewpoints, or responses, six (21%) were related to applying skills outside of the classroom setting. This theme included the following phrases: relate careers to STEM, problem-solve, succeed beyond math, find similarity with other subjects, consider the living world, make wise decisions, be good citizens, be critical thinkers, find solutions to world problems, and contribute positively to the world. For example, P2 said, "I want them to realize that what they learned in my class makes sense for something else and that they can transfer what they learned to other things." Similarly, P7 expressed, "When they grow up, I want them not to become part of the problems the world has, but part of the solutions and to contribute meaningfully, positively, and intelligently to the world."

Make students feel valued. Several participants also agreed that making students feel valued was an important goal while teaching STEM subjects. Of the 28 phrases, viewpoints, or responses, four (14%) were related to making students feel valued. The theme of making students feel valued included providing a safe learning environment, making students feel cared for, making students feel known and understood, and developing student-teacher relationships. P4 emphasized the importance of building relationships with students, sharing the following:

> Building relationships with students is so fundamental I don't even make it a goal, it's piece in pursuit of the other goals. Helping students feel known and understood and not alone in this world is such an important component of teaching.

Content knowledge. Content knowledge was the least frequent theme related to participants' goals while teaching STEM subjects. Of the 28 phrases, viewpoints, or responses, three (11%) were related to developing content knowledge. This theme included having students meet grade level standards, numeracy, and learning the content. For instance, P4 said, "Numeracy… people would never go around bragging about how illiterate they are but somehow our society has allowed for that, so I want my students numerically literate."

Interview question 8. IQ8 asked, How do you measure the success of your teaching practices? After an analysis of all interview responses to IQ8, a total of 26 phrases, viewpoints, or responses related to how participant's measure the success of their teaching practices. The responses were grouped into five common themes. The themes that emerged were as follows: (a) student deliverables and assessments, (b) changes in attitude toward STEM, (c) informal student feedback, (d) unsure, and (e) STEM career pursuance (see Figure 7).

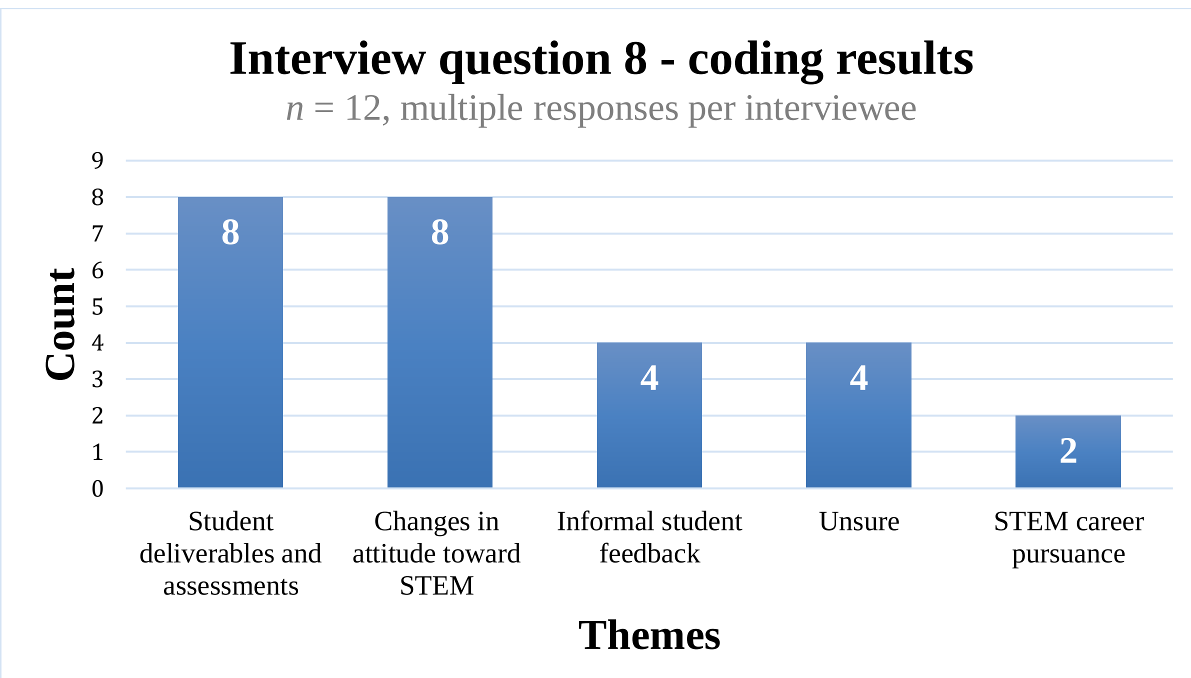

Figure 7. The most notable ways to measure the success of teaching practices. This figure demonstrates the five common themes that emerged from the responses to IQ8. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Student deliverables and assessments. IQ8 identified that one of the most frequent methods teacher's use to measure the success of their practices was student deliverables and assessments. Of the 26 phrases, viewpoints, or responses, eight (31%) of the responses collected were related to student deliverables and assessments. This theme included the following phrases: learning target trackers, assessments, student deliverables, student creations, SAT scores, and quantitative measures. For example, P3 stated, "I use their assessments as the success of content and skill acquisition." P4 further elaborated on student deliverables, saying,

> When they have a project that's really cool and I'm able to see that in production is an amazing thing. We do events at the end of the year where they showcase what they've been working on and seeing that they can create something with something they now know how to do, that's what I'm looking for.

Changes in attitude toward STEM. Changes in attitude toward STEM ranked in equal frequency as student deliverables and assessments. Of the 26 phrases, viewpoints, or responses, eight (31%) of the responses related to observing changes in students' attitudes toward STEM subjects as an emerging theme for measuring the success of teaching practices. The theme of changes in students' attitude toward STEM included the following phrases: feeling good, feeling cared for, reading the room, being excited to come to class, discussing concepts outside of class, having rich academic discussions, increased enrollment in voluntary classes, and changes in student attitude toward STEM. P9 described a unique situation where she was part of "flipping" the curriculum at a high school to a physics-first, inquiry-based approach. To measure the success of this flip, she specified, "We used instruments before and after incorporating the flip to inquiry-based learning to assess student attitudes, feelings and abilities toward science. We found that students who did active and inquiry learning felt better about science than their counterparts." Furthermore, P4 explained the value in feeling the class, stating, "I like to see a few things: are they walking out saying that was so cool, are they coming in ready and curious as to what we're going to do, and are they having rich academic discussions about the material." Lastly, P10 shared, "One of the things I've felt has been a big indication of interest in math is when we have more students enrolled in math classes than we do in our school, when we have students double enrolled by choice."

Informal student feedback. The third theme, informal student feedback, yielded a frequency of four (15%) responses of the 26 phrases and viewpoints in response to IQ8. The phrases related to informal student feedback included feedback surveys, end of year cards, having students rank their knowledge and thank you notes. P6 stated, "My favorite is a thank you note at the end of the semester." Similarly, P2 shared, "I hope that at the end of the year, the student either in person or through a note would say, 'I really appreciated the way you taught and now I feel more comfortable and confident in future math classes and classes in general.'"

Unsure. Of the 26 phrases, viewpoints, or responses to IQ8, four (15%) related to being unsure of how to measure the success of teaching practices. The theme of unsure included participants indicating that there is no true measure, they didn't know how to measure the success of their practices, and several shared that it was a challenging question. For example, P5 shared, "It's just a roller coaster. Some days I go home thinking I did amazing and other times I'm at a loss and feel like I don't know."

STEM career pursuance. The last theme, tracking STEM career pursuance, ranked the lowest frequency of how participants measured the success of their teaching practices. Of the 26 phrases, viewpoints, or responses to IQ8, two (8%) related to tracking students' pursuance in STEM-related disciplines or careers. For example, P3 noted, "Since our school goes through

12th grade I get to see what they end up wanting to study in college." Additionally, P8 noted, "I look at the number of students that go into those [STEM] majors and fields after they leave here. As a school we measure our success by an increased number of students going into STEM majors and being successful."

Interview question 9. IQ9 asked, What behaviors do you believe indicate an increased interest in the subject matter? The responses from IQ9 were crucial to understand how teachers measure the success of their practices of increasing student interest in STEM subjects. After an analysis of all interview responses to IQ9, a total of 22 phrases, viewpoints, or responses related to the specific behaviors that indicate an increased interest in the subject matter. The responses were grouped into five common themes. The themes that emerged were as follows: (a) participate in peer discussions, (b) take ownership of learning, (c) attentive, (d) dependent on the learner, and (e) attitude change (see Figure 8).

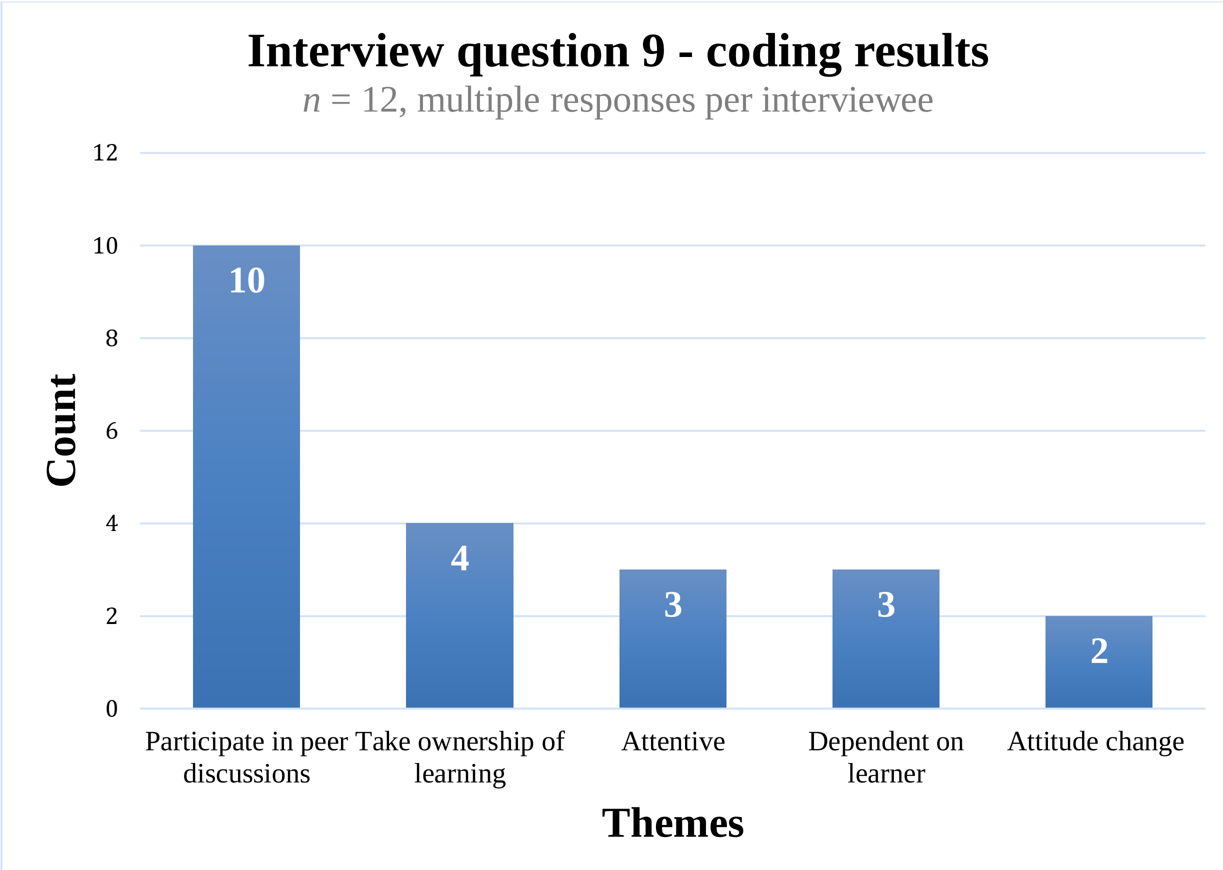

Figure 8. The notable behaviors that indicate an increased interest in the subject matter. This figure demonstrates the five common themes that emerged from the responses to IQ9. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Participate in peer discussions. IQ8 identified participating in peer discussions as the most frequent theme regarding behaviors that indicate an increased interest in STEM subjects. Of the 22 phrases, viewpoints, or responses, nearly half (45%) of the responses were related to behaviors that indicate an increased interest in the subject matter. The theme of peer discussions included the following phrases: talkative students, noisy classrooms, engaging discussions, academic conversations, content arguments, asking questions, engaging within groups and expressing curiosity. For instance, P5 shared, “When I have a loud classroom with people talking about the content, especially when they don’t see me there watching them, and they're having these academic conversations, that makes me feel accomplished.” Likewise, P3 said, “My students tend to be pretty noisy and talkative but they're talking about what we're doing and asking questions that are on topic, which tells me things are going the way I want them to."

Take ownership of learning. The second theme, taking ownership of learning, yielded a frequency of four (18%) responses of the 22 phrases, viewpoints or keywords in response to IQ9. The theme of taking ownership of learning includes the following: students direct their own learning, working hard, participating in supplementary material, answering their own questions, and attempting to do more than requirements. P8 shared his thoughts on the value of students directing their learning, stating, "A desire to ask questions and pursue knowledge on their own. I think when you get to that point where the student is starting to direct their own learning, then they're really engaged in the material." Similarly, P9 shared, "Curiosity, asking what if questions, and when students come up with their own ways to solve problems. We also had a student start a math group, that optional work shows an increased interest in the subject"

Attentive. The next most frequent theme in response to IQ9 involved being attentive. Of the 22 phrases, viewpoints, or responses, three (14%) were related to being attentive. The label attentive included the following phrases: appearing engaged, actively participating, writing ideas, taking notes, being alert, attentive, having eye contact, and paying attention. For example, P2 shared, "I think it's more of an alertness, awareness, and attentiveness in the classroom where regardless of what the topic is their eyes are looking up and they are paying attention."

Dependent on the learner. Of the 22 phrases, viewpoints, or responses, three (14%) were related to behaviors being dependent on the learner. More specifically, three participants shared that the behaviors that indicate an increased interest in the subject matter varies between introverted and extroverted students. As an example, P7 shared, "This is a delicate question because you have introverts and extroverts that will engage differently." Similarly, P3 noted, "It really varies since some kids are introverted so I won't see a lot of outward stuff."

Attitude change. The final theme ranked in frequency regarding the behaviors that indicate an increased interest in the subject matter was a change in attitude. Of the 22 phrases, viewpoints, or responses, two (9%) related to a change in student attitudes toward the subject matter. For instance, P9 noted a meaningful example of when a student changed his attitude toward science, explaining,

> I had a student named Greg who was a basketball player and not interested in STEM. It was so great to see him in the lab one day and say, 'I totally get this' and change his perception of who he was as a person. It's nice anytime that I can flip the negative self -talk around and watch students gain confidence.

Summary of RQ3. Research question 3 sought to identify how K-12 teachers measure the success of their practices of increasing student interest in STEM subjects. A total of 15 themes were identified by analyzing phrases, viewpoints, or responses from IQ7, IQ8, and IQ9. The 15 themes identified were as follows: (a) instill grit and empower students, (b) make STEM enjoyable, (c) apply skills in real world situations, (d) make students feel valued, (e) content knowledge, (f) student deliverables and assessments, (g) changes in attitude toward STEM, (h) informal student feedback, (i) unsure, (j) STEM career pursuance, (k) participate in peer discussions, (l) take ownership of learning, (m) attentive, (n) dependent on learner, and (o) an attitude change.

Research Question 4

The fourth research question (RQ4) asked, What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?

The researcher asked a total of three interview questions to the participants in order to answer RQ4. The three questions related to RQ1 included the following:

1. What recommendations do you have for novice teachers to succeed in teaching students that are not interested in STEM subjects?
2. What can academic leaders do differently to better support STEM teachers?
3. Is there anything else you would like to add?

To identify the recommendations K-12 teachers would make for future implementation of strategies to increase student interest in STEM subjects, the researcher analyzed the responses from the participating teachers and identified recurring themes and similarities in response to the three interview questions.

Interview question 10. IQ10 asked, What recommendations do you have for novice teachers to succeed in teaching students that are not interested in STEM subjects? Through an analysis of all responses to IQ10, a total of 27 phrases, viewpoints, or responses were identified regarding the recommendations K-12 teachers had for novice teachers to succeed in teaching students with little interest in STEM subjects. The phrases, viewpoints, or responses were grouped into the following five themes: (a) incorporate active learning strategies, (b) be flexible and create with curriculum, (c) develop student-teacher relationships, (d) develop professional relationships, and (e) be a lifelong learner (see Figure 9).

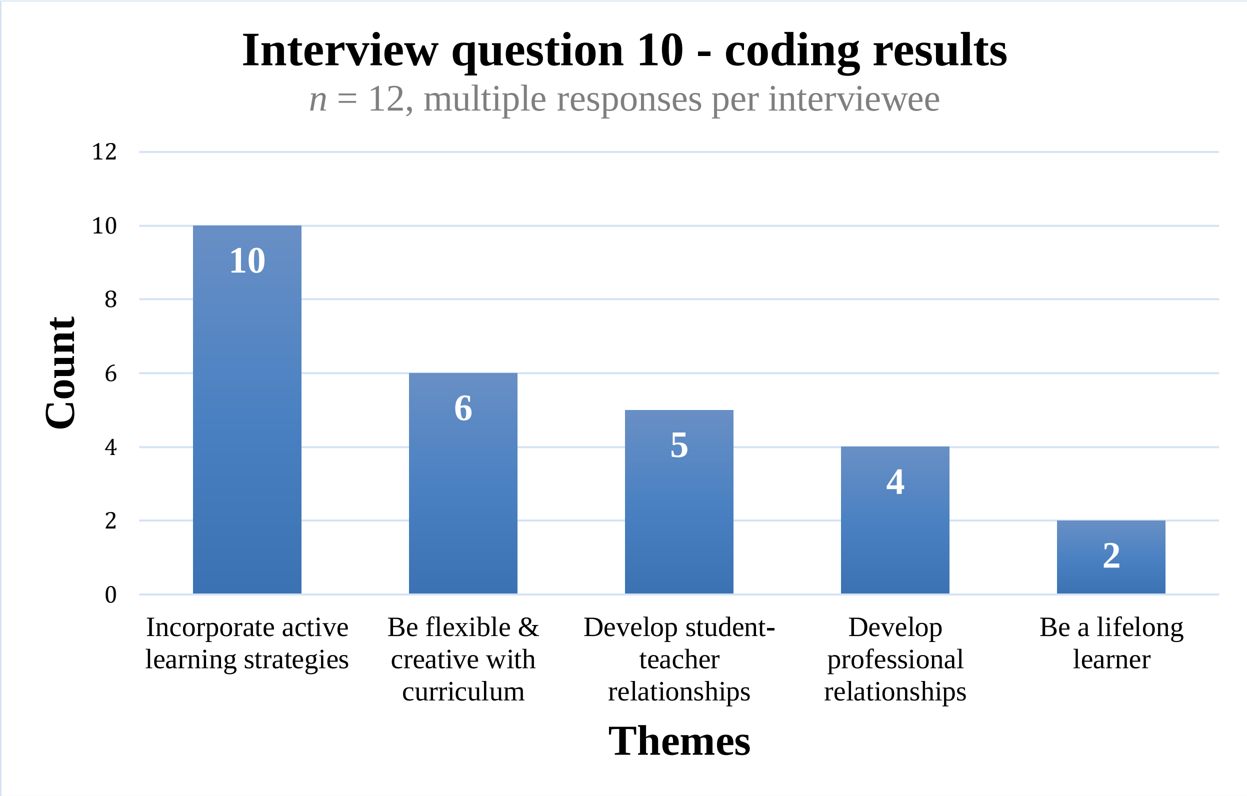

Figure 9. The recommendations teachers would advise to novice teachers with regard to teaching students that are not interested in STEM subjects. This figure demonstrates the five common themes that emerged from the responses to IQ10. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Incorporate active learning strategies. Incorporating active learning strategies emerged as the highest-ranking theme for advice for novice teachers to succeed in teaching students with little to no interest in STEM subjects. Of the 27 phrases, viewpoints, or responses, 10 (37%) of the responses collected were related to incorporating active learning strategies. The theme of incorporate active learning strategies included the following: hands-on, pair with technology, project-based, frame as challenges, problem-based, relatable content, promote discussion, show applications, integrate into other subjects, make students feel part of the learning process, make STEM careers visible, activities, fun group projects, and connect STEM with other subjects. For instance, P11 provided an example of how to incorporate active learning strategies in a math classroom, explaining,

> As many activities that you can do to engage them, like a fun project that they can do as a group about something they can relate to and are interested in. Like if they are interested in basketball and you are learning about probabilities, you can have them shoot free throws outside to make it fun.

Similarly, P1 noted, “Nothing makes students more excited than actually using the stuff themselves, so make it as hands-on as possible, have them see it with their own eyes and experience it with their own hands.” A majority of the participants also recommended making the curriculum relatable and showing students how to apply learned knowledge.

- “Show them how they can apply what we’re learning and what we can do with the topic” (P6).
- “Find ways to make STEM about other things. Show students that there is STEM in art, history, language, and PE. By doing that, you can attract the athletic, artistic, and quiet students” (P7).
- “Find out what is interesting to them and what they’re scared of. From there, make the content relatable to them” (P5).

Be flexible and creative with the curriculum. The second most frequent theme, being flexible and creative with the curriculum, yielded a frequency of six (22%) responses. The theme of being flexible and creative with the curriculum included the following phrases: do not focus on textbook, do not be bound to the syllabus, loosen up, open-ended assignments, leave room for student creativity, do not focus on grades, make the lesson a game, depth over breadth, prioritize fewer topics, and focus on habits instead of content. P9 had an interesting perspective, recommending that novice teachers prioritize important topics and make themselves comfortable with letting go of other concepts. Specifically, P9 noted,

> I would say depth over breadth. I used to think that I just had to cover the curriculum and now I would say go deeper than shallow. Make sure students are getting a deeper understanding instead of just checking off a box. It's more about the habits than the content, so invest in the bigger topics.

Furthermore, P2 shared, "New teachers are always worried about their year-long syllabus they've laid out and I think it's so easy for us to get worried about the quantifiable aspects of being a teacher." Lastly, P3 stated, "I like to have assignments open, so they can have different ways of accomplishing or addressing the task."

Develop student-teacher relationships. Developing student-teacher relationships ranked as the third most frequent theme in response to IQ10. Of the 27 phrases, viewpoints, or responses, five (19%) were related to developing student-teacher relationships. This theme included the following: create a welcoming learning environment, gain student's trust, show your weaknesses, connect with them early on, understand their past experiences, create a growth mindset, show that you care, and show your passion. P2 shared his passion for creating relationships with students, stating,

> What teachers need to do is make students feel like this is a place where they want to be, and then they will create understanding, comradery, and community in the classroom. It's not a one-way relationship. I think kids need to see that they are able to move you in some way and they have just as much of a change of impacting you as you do of them.

Develop professional relationships. The next theme, developing professional relationships, reflected 15% of the phrases, viewpoints, or responses from IQ10. This theme included the following recommendations: get to know other teachers, develop a community, find people to connect with, connect with teachers of different perspectives. For instance, P12 indicated, "In my experience, you can't really go at this path alone. Building those teams and having people who come from different perspectives and backgrounds is pretty valuable." Similarly, P10 shared, "Collaborate! A lot of my great ideas came from collaboration, so definitely working together is key."

Be a lifelong learner. The final theme, being a lifelong learner, consisted of 7% of the phrases, viewpoints, or responses in response to IQ10. Specifically, participants shared the importance of attending professional development opportunities and engaging in reading books related to their respective subjects. For example, P10 shared,

> We want our students to learn so we have to be learners. So, read books on growth mindset, pedagogy, diversity, and inclusion. Sometimes students are not interested in a subject because they don't see people like them in the fields, so having a good understanding of what people go through is helpful.

P4 shared a similar recommendation, communicating, "I'm having everyone in the math department read 'Necessary Conditions' and it's been really inspirational for all of us in terms of pedagogy and connecting with the students."

Interview question 11. IQ11 asked, What can academic leaders do differently to better support STEM teachers? After an analysis of all interview responses to IQ11, a total of 34 phrases, viewpoints, or responses related to what academic leaders could do differently to better support STEM teachers. The responses were grouped into five different themes. The themes that emerged were as follows: (a) invest in STEM specialists, resources, and integration, (b) provide funding for professional development and resources, (c) additional time, and (d) allow for classroom autonomy (see Figure 10).

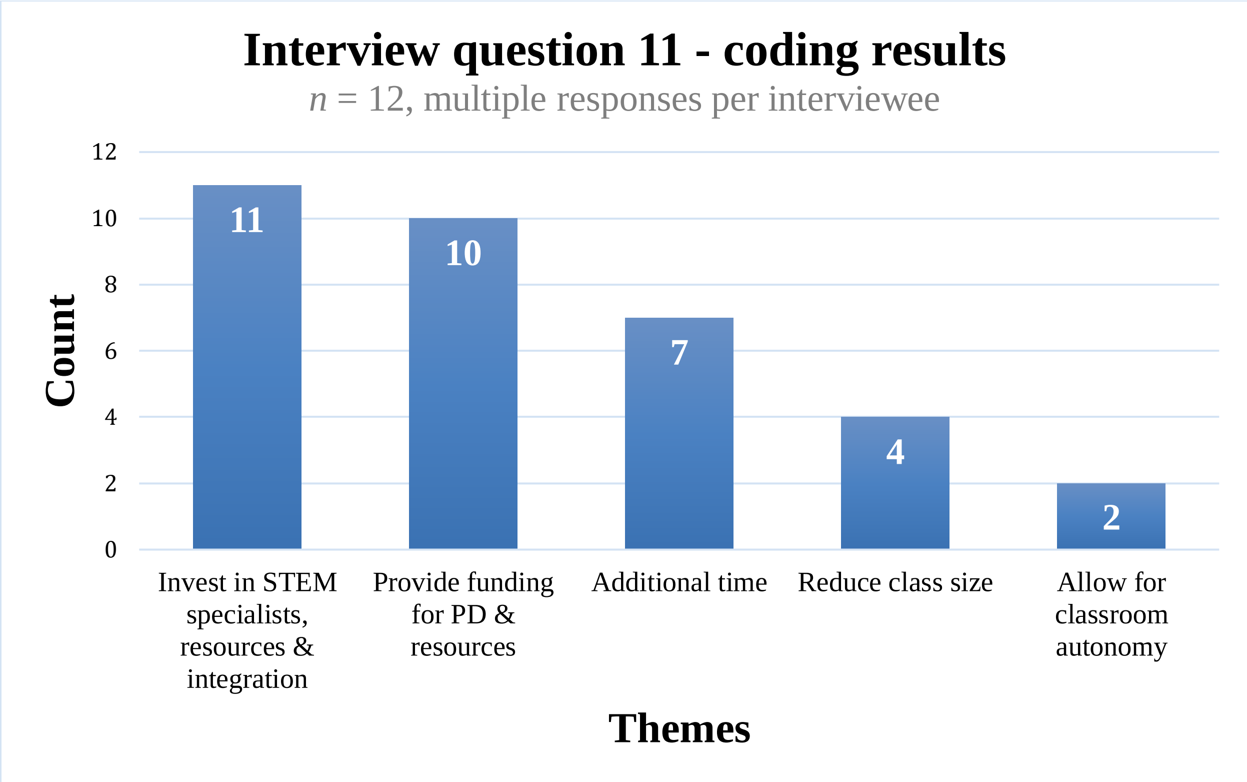

Figure 10. The notable responses regarding what academic leaders could do differently to better support STEM teachers. This figure demonstrates the five common themes that emerged from the responses to IQ11. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Invest in STEM specialists, resources, and integration. IQ10 identified investing in STEM specialists, resources, and integration as the most frequent themes regarding what academic leaders can do differently to better support STEM teachers. Of the 34 phrases, viewpoints, and responses, 11 (32%) of the responses collected were related to investing in STEM specialists, resources, and integration. The phrases that were cited included the following: investing in science specialists, access to resources, support STEM learning environments, curriculum resources, hiring content specialists, providing pre-made curricula and activities, understanding the importance of STEM integration, and bringing together separate silos. For instance, several participants expressed a desire to have access to already developed and tested STEM activities and resources.

- “The more we can connect teachers to resources the better” (P9).
- “It’s hard enough to get the concepts across, teachers, especially in math, need more support in integration and showing students how they can apply concepts to the real world” (P12).
- “I wish there was a place where everything is put together and is tried and true. So, providing curriculum resources to teachers would be helpful” (P5).
- “It’s really challenging for any new teacher, and even though there are a lot of resources out there, I wish that they were all compiled in one place where it would be easier to swift through them” (P8).

More so, P12 noted, “Institutions need to understand why STEM and STEM integration is so important. Why the way we’ve been doing things could be improved.” Lastly, P9 elaborated on the unique needs of STEM subjects, stating, “As far as administrators, they have to realize that STEM fields require different needs.”

Provide funding for professional development and resources. A majority of participants also expressed the importance of having funding available for professional development and other resources. Of the 34 phrases, viewpoints, and responses, 10 (29%) of the responses collected were related to needing funding for professional development and other resources. The phrases that were cited in this theme included the following: increase STEM budget, professional development opportunities, financial support, sufficient training, ongoing professional development, and provide a healthy budget for projects. For example, P5 shared, “Financial support to be able to put together these amazing experiences that would make the kids more engaged would be impactful.” Similarly, P7 explained, “Encourage and support professional development in the school, and have a healthy budget set aside for it, almost require it in a way.”

Meanwhile, P6 shared, “I think the biggest thing they [academic leaders] can do is get teachers sufficient training for classes outside of the traditional math and science curriculum, including ongoing professional development. Especially in technology where things change so fast.”

Additional time. The third most frequent theme, having additional time, corresponded to seven (21%) of the responses to IQ10. Participants referred to the need for more instructional time and preparation time. More specifically, the theme of additional time included the following phrases: time to develop projects, time for innovation, time for extra help with students, time to create, time to collaborate, instructional time, and time to build peer communities. For example, P3 stated, “Providing time for us to bounce ideas off on another and collaborate would be nice. How many hours do we even have available to work on innovative teaching projects?” P12 also shared his frustrations of having minimal instruction time and time with his colleagues, sharing:

> It would be nice to have more instructional time. When I have to jam together a lesson in an hour because that’s all the time I have, that sucks. Also setting aside intentional time and a space for collaboration is so important. Anytime I’ve had opportunities to make real connections with other teachers, the quality of content that comes out of those meetings and conversations is incomparable.

Reduce class size. Of the 34 phrases, viewpoints, and responses, four (12%) of the responses collected from IQ10 were related to reducing class size. The participants expressed a desire to have smaller class sizes, lower teacher to student ratios, and an intimate class setting. P7 expressed, “Number one on my list is to have a small, intimate class setting. I think that is crucial.” Additionally, P3 noted, “I think class size is really important and student load, like how many students teachers see over the course of a day, and making sure the teacher’s workload is doable.”

Allow for classroom autonomy. The least frequent theme in response to IQ10, allowing for classroom autonomy, yielded a frequency of two (6%) responses. The theme of classroom autonomy included having the flexibility to try new experiments and implement new ideas. For example, P8 shared, "I've been lucky in all of my situations that I've had a lot of autonomy in the classroom. I think if there is a teacher who is really motivated and has a lot of ideas, the administration should give them the flexibility to kind of run with that."

Interview question 12. IQ12 asked, Is there anything else you would like to add? After an analysis of all interview responses to IQ12, a total of 11 phrases, viewpoints, or responses related to anything else the participants wanted to add. The responses were grouped into three different themes. The themes that emerged were as follows: (a) diversity in STEM, (b) classroom climate, and (c) group interactions (see Figure 11).

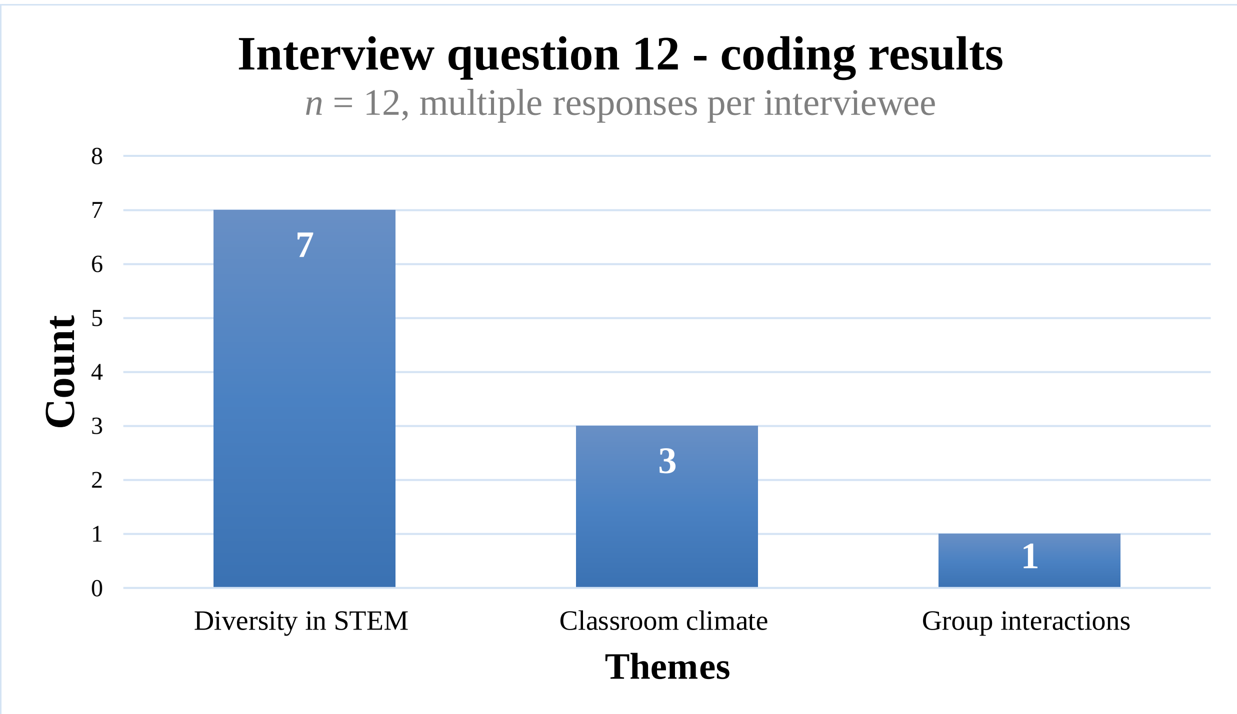

Figure 11. The notable responses referring to anything else the participants wanted to add. This figure demonstrates the three common themes that emerged from the responses to IQ12. The data being represented are in a decreasing order of frequency. Each number represents the number of participants who made a direct or indirect statement that corresponded to the respective theme.

Diversity in STEM. When asked if there was anything else they'd like to add, a majority of participants chose to discuss the importance of having diversity in STEM. Of the 11 phrases, viewpoints, or responses, seven (64%) related to diversity in STEM. The responses included the following phrases: engaging all genders, creativity in STEM, differentiation, involving more women in tech, closing the gender gap in STEM, diversity is an asset, supporting underrepresented communities in STEM, and building interest beyond the traditional curriculum. For example, P1 expressed, "It's interesting to see how gender is a factor in student interest and the impact teachers have on that. So, I would say it's really important for teachers to remember that and make sure they're trying to engage everyone." P8 shared the same concern, stating, "I do feel like closing the gender gap in STEM is crucial. As technology continues to advance it's incredibly important for us to have a diverse group of people creating it. Diversity is an asset in any context." Lastly, P9 shared, "My big, big, personal thing is women and people of color. That is the two underrepresented categories in science, and we need to realize that this needs to change and put more effort into that."

Classroom climate. The second most common theme in response to IQ12 was classroom climate. Of the 11 phrases, viewpoints, or responses, three (27%) were related to classroom climate, including the following: teacher-student relationships, welcoming mistakes, making sure students feel supported, creating a climate to ask for help, and providing unstructured classroom time. For example, P9 shared, "Helping to create a climate where it's a normal thing for students to stop by and ask for extra help is super important. That also includes being welcoming and making sure your students feel supported." Additionally, P2 shared, "that continual emphasis on trial and error, building relationships with your students is crucial. I always tell my students it's great to be wrong."

Group interactions. The least-frequent theme in response to IQ12 was group interactions. Of the 11 phrases, viewpoints, or responses, one (9%) was related to the importance of group interactions. For example, P6 noted, "Group interactions, project-based learning, and just the teamwork aspect is a really important part of education, especially for motivating students."

Summary of RQ4. Research question 4 sought to identify the recommendations K-12 teachers would make for future implementation of strategies to increase student interest in STEM subjects. A total of 12 themes were identified by analyzing phrases, viewpoints, or responses from IQ10, IQ11, and IQ12. The 12 themes identified were as follows: (a) incorporate active learning strategies, (b) be flexible and create with curriculum, (c) develop student-teacher relationships, (d) develop professional relationships, and (e) be a lifelong learner, (f) invest in STEM specialists, resources and integration, (g) provide funding for PD and resources, (h) additional time, (i) reduce class size, (j) allow for classroom autonomy, (k) diversity in STEM, (l) classroom climate, and (m) group interactions.

Chapter 4 Summary

The purpose of this study was to identify the best practices exemplary K-12 teachers employ to increase student interest in STEM subjects, the challenges K-12 teachers face in increasing student interest in STEM subjects, the methods K-12 teachers use to measure the success of their practices, and the recommendations exemplary K-12 teachers have for future implementation of strategies to increase student interest in STEM subjects. To accomplish this task, 12 participants who teach in schools with exemplary STEM programs were recruited. Each participant was asked 11 open-ended questions that were designed to address the following four research questions:

1. RQ1: What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?
2. RQ2: What challenges do K-12 teachers face in increasing student interest in STEM subjects?
3. RQ3: How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?
4. RQ4: What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?

Data for this study was collected through 12 semi-structured interview questions which the researcher transcribed and coded. The codes for each interview question were then grouped into themes. The codes and themes were validated through an inter-rater review process. Furthermore, data analysis was conducted by employing the phenomenological approach discussed in Chapter 3. The data yielded a total of 48 themes. Table 4 provides a summary of the themes that were identified through the data analysis process. Chapter 5 presents a discussion of themes, along with implications, recommendations, and conclusions of the study.

Table 4

Summary of Themes for Four Research Questions

RQ1. What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?	RQ2. What challenges do K-12 teachers face in increasing student interest in STEM subjects?	RQ3. How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?	RQ4. What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?
Active learning	Student intrinsic motivation	Instill grit and empower students	Incorporate active learning strategies

(continued)

RQ1. What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?	RQ2. What challenges do K-12 teachers face in increasing student interest in STEM subjects?	RQ3. How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?	RQ4. What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?
Facilitated learning	Previous negative STEM experiences	Make STEM enjoyable	Be flexible and creative with the curriculum
Social constructivist	Consistent teacher engagement	Apply skills outside of the classroom	Develop student-teacher relationships
Differentiated learning	Differentiation	Make students feel valued	Develop professional relationships
Authentic learning	Collegiality	Content knowledge	Be a lifelong learner
Create ownership	Continuing education opportunities	Student deliverables and assessments	Invest in STEM resources and integration
Enrichment activities	Curriculum resources	Changes in attitude toward STEM	Additional time
Instructional variety	Administrative support	Informal student feedback	Reduce class size
Integrate STEM into other subjects		Unsure	Allow for classroom autonomy
Lived experiences		STEM career pursuance	Diversity in STEM
Internal drive		Participate in peer discussion	Classroom climate
Content knowledge		Take ownership of learning	Group interactions
Professional development		Attentive	
		Dependent on learner	
		Attitude change	

Note: This table represents a summary of all the themes derived through the data analysis process.

Chapter 5: Conclusions and Recommendations

Introduction

Early STEM education plays a crucial role in developing a competent STEM workforce and can serve as an indicator of whether students pursue degrees in STEM-related fields (Tai et al., 2006). Although significant efforts have been made to provide students with meaningful STEM experiences to help increase student interest in STEM subjects, further instructional reform should take place at the K-12 level to increase interest in STEM subjects and attract more students to participate in STEM-related disciplines and careers. The purpose of this study was to determine the best practices and strategies teachers employ, the challenges they encounter, the methods to measure the success of their practices, and the recommendations they would make for future implementation of strategies regarding increasing student interest in STEM subjects. The teachers who participated in this study were genuinely passionate about the phenomenon of increasing student interest in their STEM-related classes. Their willingness to share their knowledge, expertise, experiences, and recommendations provided a rich source of data which led to insight into how teachers should approach teaching STEM subjects.

The findings of this study aim to contribute to the existing literature on best practices and strategies relating to increasing STEM interest. More so, this research aims to look beyond foundational teaching requirements and carefully assess the practices that exemplary STEM teachers implement in their daily instruction and identify the challenges they face during the implementation of these practices. This chapter commences with a brief summary of the data presented in Chapter 4, followed by a discussion of the key findings from the study. Additionally, this chapter explores the implications of the study and provides a framework for teachers to follow to increase student interest in STEM subjects. The framework includes the set of strategies and practices that were identified through the data collection and analysis process.

Lastly, Chapter 5 concludes with a summary of the researcher's recommendations for future research and a few notes from the author's perspective.

Summary of the Study

This qualitative, phenomenological study investigated the best teaching practices, teaching challenges, measures of success, and recommendations for future implementation of strategies utilized by K-12 teachers to increase student interest in STEM subjects. The following four research questions were addressed to understand the phenomenon of student interest in STEM subjects.

- RQ1: What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?
- RQ2: What challenges do K-12 teachers face in increasing student interest in STEM subjects?
- RQ3: How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?
- RQ4: What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?

The researcher recruited participants for this study through Niche (https://www.niche.com), which had a list of the best schools for STEM in the Los Angeles area. Niche provided a list of schools that would qualify for this study. While the initial site did not list a directory of teachers or contact information, both were found by directly clicking on the link to the school's website. A sample of 12 participants were identified for this study. Participants had at least 3 years of teaching experience in a STEM-related discipline and worked at one of the schools listed under "2020 best schools for STEM in the Los Angeles area" (Niche, 2019).

Recruited participants also needed to be available to participate in a face-to-face interview, or virtual interview using a video conferencing tool. Furthermore, to ensure maximum variation and include representation of diverse backgrounds, the researcher examined the participants' employment position, education level, and geographic location. More specifically, the researcher ensured to select participants from (a) multiple schools, (b) genders, and (c) ethnic backgrounds.

The researcher collected data for this study through semi-structured interviews with 12 participants. The participants were asked 11 open-ended questions that directly informed a specific research question. The questions were validated through a three-step validity process, including (a) prima facie validity, (b) peer-review validity, and (c) expert review. Furthermore, reliability was established by conducting one pilot interview. The researcher audio recorded the interviews and later transcribed into a Microsoft Word document. The transcribed data was then analyzed and coded to determine common themes. The themes were reviewed by two doctoral students through an interrater review procedure, as outlined in Chapters 3 and 4. After coding each interview and completing the interrater review procedure, the researcher summarized the findings of the study into 11 bar graphs, which identified the frequency of key phrases, viewpoints, and responses.

Summary of Findings

The findings of this study are intended to identify the best practices K-12 teachers employ and the challenges they face when increasing student interest in STEM subjects. The researcher noted that the individuals who agreed to participate in the study were genuinely passionate about increasing student interest and participation in STEM. Therefore, all participants provided rich, meaningful data in response to the 11 semi-structured interview questions. The data analysis yielded 48 significant themes. This section provides a summary of the general findings that emerged throughout all of the interview questions. The following section will present the key findings for each research question, and the findings will be compared to the existing literature to determine if the findings agree, disagree, or contribute to the existing literature on student interest in STEM subjects.

As an icebreaker, the researcher asked the participants if they felt that their students were typically engaged in their STEM classes. Overall, the participants believed that their students were typically interested in the subject, but primarily credited this interest to their instructional approaches. Additionally, participants who taught varying levels of classes noted that student interest was dependent upon the class. More so, a universal theme that emerged from every research question was an emphasis on relationships. Notably, while the researcher's intent was to determine instructional strategies used to increase student interest, and the interview questions were intended to probe participants to discuss their instructional practices, all participants chose to discuss the importance of building relationships. The relationships mentioned by the participants included both with students and with their colleagues. According to these findings, teachers should make connections and personal relationships with their students before attempting to teach the content. Additionally, teachers should be provided with sufficient time to build relationships and collaborate with their colleagues. The current research regarding the impact of positive student-teacher relationships supports this finding, which states that as the quality of student-teacher relationships increases, so do positive social, behavioral, and engagement outcomes for students (Decker, Dona & Christenson, 2006). However, research connecting the relationships between students and teachers in a STEM classroom was limited. Since the theme of relationships was such a significant finding in this study, future research should focus on the impact that positive student-teacher relationships could have on student outcomes in a STEM classroom.

Discussion of Findings

The following section provides an in-depth discussion of the themes that emerged from the interview questions as they relate to each research question. The findings were compared to the existing literature on the strategies to increase student interest in STEM subjects to determine if they agree, disagree, or contribute to the existing literature.

Results for RQ1. RQ1 asked, What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects? An analysis of the themes obtained from IQ1 through IQ3 indicated that the strategies and practices employed by K-12 teachers to increase student interest in STEM subjects revolved around the following areas:

- Applying a variety of nontraditional instructional techniques and strategies
- Creating an authentic, safe classroom environment
- Having a genuine interest and personal lived experiences in the subject

Discussion of RQ1. The key findings of RQ1 indicate that teachers can promote student interest in STEM subjects by applying a variety of nontraditional instructional techniques and strategies. Nearly every participant expressed that they used multiple approaches while teaching STEM subjects, such as active learning strategies. This finding agrees with the existing literature, which suggests that the instructional strategies commonly associated with classroom engagement in STEM subjects include problem-based learning (PBL), project-based learning (PjBL), inquiry-based learning, collaborative learning, and cooperative learning (Froyd et al., 2013). These suggested strategies are also all supported by a social constructivist view on learning (Ertmer & Newby, 2013), which was another common finding to RQ1. More so, as indicated in the existing literature on best practices, when teachers incorporate active learning strategies and opportunities for discussion, students become more engaged in the learning, connected to the subject matter, and have a higher level of retention (Henderson et al., 2012). Lastly, these findings agree with Piaget's (1928) suggestion for teachers to provide students with opportunities for individualized work, where they could construct learning with minimal guidance.

Another principal finding is in regard to creating an authentic, safe classroom environment. The participants suggested that creating a positive, authentic learning environment should be a priority for teachers when attempting to increase interest and engagement in STEM topics. The classroom environment involves providing students space where they are comfortable with asking questions, making mistakes, and providing feedback to their teachers. Additionally, within these environments students can develop meaningful and memorable experiences, and then they can associate those experiences with STEM subjects. Lastly, the classroom environment should be authentic, where concepts relate to real-world situations, and topics are relevant to students' interests. The existing literature agrees with these findings, suggesting that students enjoy the experience of participating in authentic projects, and these authentic experiences can impact student career aspirations and interest in STEM subjects (Beier et al., 2019).

The final key finding that emerged is that exemplary teachers can provide meaningful context by having a genuine interest and personal lived experiences related to the subject matter they teach. Participants shared that, although content knowledge was an essential factor when teaching STEM subjects, teachers should also know how to teach the specific subject. These pedagogical skills may be achieved through the experiences they have had while teaching the subject and their diverse backgrounds related to the subject. Participants also shared that having a personal passion for the subject matter helped provide a meaningful context. Therefore, genuine interest and personal lived experiences in the subject can increase teachers' knowledge about the subject, which can help improve how it is delivered and accepted by students. This finding is in agreement with the existing literature, which suggests that successful teaching and learning require teachers to have a deep understanding of the subject-specific content, as well as a thorough understanding of the teaching activities and strategies that help students understand the content deeply enough to be capable of asking exploratory questions (Shulman, 1987). Furthermore, this pedagogical content knowledge (PCK) includes the knowledge of difficulties students may encounter as they learn a specific discipline, the learning trajectories students come across in order to achieve understanding, and a set of known strategies that may assist students with overcoming difficulties they may encounter (NRC, 1999).

Results for RQ2. RQ2 asked, What challenges do K-12 teachers face in increasing student interest in STEM subjects? An analysis of the themes obtained from IQ4 through IQ5 indicated that the challenges faced by K-12 teachers when attempting to increase student interest in STEM subjects revolved around the following areas:

- Student mindset and attitudes toward STEM
- Time for collegiality, innovation, and instruction
- Access to relevant and applicable curriculum

Discussion of RQ2. The key findings of RQ2 indicate the broad areas in which the participants face challenges in increasing student interest in STEM subjects. One of the most prominent challenges in response to RQ2 was students' mindset and attitudes toward STEM. Participants shared that many students have had previous negative experiences in STEM courses, which make them not identify as STEM students and make them doubtful of their abilities.

According to the participants, this paralyzed mindset can cause students to shut down, not participate, not take risks, overcomplicate the material, and be resistant to the material. This finding supports the existing literature, which indicates that experiences during early education can impact students' perceptions toward STEM and cultivate a future interest in STEM degrees and careers (Hanover Research, 2012).

Second, teachers expressed the need for additional time as a resource, which may indicate that time is also a critical factor in increasing student interest in STEM subjects. More specifically, the participants communicated the need for more time for collegiality, innovation, and classroom instruction. For instance, participants shared that they do not have enough time to collaborate and brainstorm with colleagues, which was crucial when trying to develop a relevant, engaging curriculum. One participant specifically mentioned that there was not enough time for innovation and preparation of differentiated curriculum. Existing literature recommends for teachers to be given sufficient time to explore different teaching strategies (Marshall & Horton, 2011). Lastly, several participants shared the need to have more instructional time to allow them to teach and assess concepts while providing students with meaningful activities. As suggested by the literature, with little instructional time dedicated to science and math, students may not have adequate time and opportunity to have meaningful experiences in STEM subjects, which is needed to ignite interest in a STEM career (NCES, 2017).

Lastly, while teachers were familiar with the methods and strategies they needed to increase engagement in the classroom, many expressed that existing curricula did not align with these strategies, making implementation a challenge. More specifically, participants shared that it would be easier to engage students further if they had access to an applicable, contextualized curriculum, and were offered more professional development opportunities. Ideally, this curriculum would support the research-based instructional strategies, and have already been tried and proved successful, while also aligning with the curriculum. More so, it was a challenge for teachers, especially in mathematics, to balance exploratory activities while also ensuring to cover the required curriculum. As the literature indicates, teacher enactment of active learning strategies may be improved when teachers are provided with materials and detailed lesson plans that support inquiry-based learning activities (R. M. Schneider et al., 2005). That said, materials alone would not be sufficient to facilitate implementation; teachers should also be given professional development opportunities to support teacher learning (Marshall & Alston, 2014). While the existing literature also suggests that STEM teachers are often unwilling to change their beliefs and practice (El-Deghaidy & Mansour, 2015), the findings of this study suggest that teachers are willing to modify their instructional approaches if they have the resources needed to succeed in implementation.

Results for RQ3. RQ3 asked, How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects? An analysis of the themes obtained from IQ7 through IQ9 indicated that the methods K-12 teachers use to measure the success of their practices in increasing student interest in STEM subjects revolve around the following areas:

- Measurement tools, such as student deliverables and assessments
- Observing student confidence, grit, and attitude change
- Hearing students engage in academic peer discussions

Discussion of RQ3. A key finding relating to how K-12 teachers measure the success of their practices in increasing student interest in STEM subjects is measurement tools, such as student deliverables and assessments. Participants expressed that they used assessments to evaluate the success of content and skill acquisition. Most participants also shared that they see if students can create something from what they have learned and showcase their learning. While some participants mentioned that tracking assessments was not a valid measure of success, current literature indicates that student achievement in mathematics and science during secondary school can also have an impact on student interest and future pursuance of a STEM career (Trusty, 2002).

Another common method K-12 teachers use to measure the success of their practices focuses on observing student confidence, grit, and attitude change. A majority of the participants noted that their goal was to have a classroom where students can associate STEM subjects with fun, memorable experiences. As students begin to enjoy the subject, participants noted that their confidence and mindset about STEM could improve, and they may realize that their goals are attainable. Participants noted that they also observe students' behaviors and their overall demeanor while they are entering and leaving the classroom. For instance, if they enter the classroom curious about the day's lesson, and leave the classroom happy and excited, then they know students were interested in the subject. Current research suggests that students are more likely to pursue a STEM-related degree and career when they are confident in their academic abilities and have an overall positive attitude toward STEM (Degenhart et al., 2007; Tai et al., 2006; Wang, 2013). Additionally, some participants noted that they were able to track students' career pursuance to assess the success of their practices.

Another prominent way teachers measure the success of their practices as it relates to STEM interest highlights the need to listen to students engage in fruitful academic discussions. Nearly all participants shared that they prefer to have a noisy classroom where students are engaging in academic conversations, rather than a quiet classroom. More specifically, participants noted that when students are asking questions and can find answers themselves, they are interested in the subject. In summary, the desire to ask questions, participate within group discussions, challenge the teacher, and carry the conversations outside of the classroom, indicate an increased interest in the subject. This finding is consistent with the current literature that supports a social constructivist view on learning, which states that learning is a shared experience that may be enhanced through social and cultural interactions (Ertmer & Newby, 2013).

Results for RQ4. RQ4 asked, What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects? An analysis of the themes obtained from IQ10 through IQ12 indicated that the recommendations K-12 teachers would make for future implementation of strategies to increase student interest in STEM subjects revolve around the following areas:

- Support non-traditional, flexible, research-based instructional strategies
- Provide special attention to STEM, including resources, integration, funding and time
- Support diversity in STEM
- Focus on relationships with students and colleagues

Discussion of RQ4. A constant finding throughout this study is the importance of implementing non-traditional, flexible, research-based instructional strategies. The best practices and instructional strategies are outlined extensively in Chapter 2 and include active learning strategies, such as problem-based learning (PBL), project-based learning (PjBL), inquiry-based learning, collaborative learning, and cooperative learning (Froyd et al., 2013). Additionally, these strategies include differentiated instruction, hands-on activities, group discussions, and contextualized lessons that apply to the student's daily lives. Participants recommend for teachers to incorporate these strategies during STEM lessons. Additionally, participants highlighted the importance of having professional development opportunities that support the implementation of these strategies. Lastly, while traditional curriculum supports covering multiple topics in a fast-paced environment, several participants recommended that teachers focus on fewer topics and ensure that students develop proficiency in those topics before moving on. This is seen in top-performing countries, where teachers present fewer topics, but in greater detail compared to the spiral curriculum standard in the U.S. (National Mathematics Advisory Panel, 2008).

A second finding for future implementation of strategies in increasing student interest in STEM subjects highlights the importance of providing special attention to STEM subjects, such as resources, integration, funding, and time. Several participants communicated that teaching STEM subjects requires a unique set of resources compared to other disciplines. More specifically, they shared that academic leaders should provide STEM teachers with more funding than other disciplines, instructional time, and curriculum resources. Additionally, institutions should consider integrating STEM subjects with subjects outside of the four STEM disciplines, such as history, art, and English, and through a combination of the four STEM disciplines. Existing literature supports applying an integrated approach to STEM education, as it may provide a more relevant and stimulating experience for content development, which may increase student interest and performance in these fields (Furner & Kumar, 2007). Investing in content specialists was also desired by participants.

The majority of participants also recommended that teachers, administrators, and policymakers support diversity within STEM fields. As discussed in Chapter 2, there are apparent achievement and participation gaps in STEM, particularly among students of varying gender, socioeconomic backgrounds, and racial backgrounds (NRC, 2007). Participants recognized that students of different racial-ethnic groups and socioeconomic backgrounds are provided with different course offerings and opportunities to learn (Tate, 2001). Furthermore, it was essential for them to note that diversity in STEM can serve as an asset and that their personal goal was to support underrepresented communities and close gender gaps in STEM fields.

Lastly, as mentioned previously, participants in this study recommended that teachers prioritize and emphasize relationships with their students and colleagues. According to these findings, students cannot successfully receive the content and learn the material without forming prior relationships with their teachers. Therefore, teachers should try to get to know their students on a personal level by learning about their interests, checking-in on them, and communicating with them. Additionally, teachers should be provided with sufficient time to build relationships with their colleagues. Participants shared that having sufficient time to collaborate with their colleagues was crucial to creating an engaging, relevant curriculum.

Implications of the Study

This research study intended to determine the best practices exemplary teachers employ to increase student interest in STEM subjects. When students are more interested and engaged in STEM subjects, they are likely to learn the material thoroughly, pursue degrees in STEM fields, and be prepared with skills needed to succeed in the 21st-century workforce. Therefore, the research findings of this study apply to and have significant implications for educators, teacher-development programs, disadvantaged and underrepresented students, and STEM initiatives.

Implications for educators. The implications for K-12 educators are inexhaustible. As discussed in Chapter 1, teachers play a crucial role in fostering positive experiences in STEM subjects for students and have the unique opportunity to inspire students to take interest in STEM subjects. Although teachers play a crucial role in determining the success of their students, a significant percentage of math and science teachers are not certified to teach in their respective subjects (NRC, 2010). Therefore, teachers who are inadequately prepared can immediately, and without the use of additional resources, incorporate the suggested best practices and strategies in their classrooms, including active learning, applied learning, differentiated instruction, and authentic learning strategies. More so, according to the findings of this study, these practices can be more successful in increasing student interest if teachers have successfully developed relationships with their students. Therefore, teachers can immediately begin to prioritize getting to know their students, building relationships with them, and creating a welcoming, safe classroom environment. Lastly, experienced teachers can also benefit from these findings by improving their own strategies and utilize their expertise to mentor novice teachers.

Implications for teacher-development programs. The findings of this study may also be utilized to establish and improve teacher-development and education programs. Most prominently, programs for pre-service teachers should emphasize having a student-centered classroom and move away from promoting a lecture-based instructional approach. Programs should also promote active learning in the classroom and provide teachers with better resources to make learning contextualized and relevant to students. More so, teachers should be exposed to the learning strategies that revolve around a constructivist approach, such as PBL, PjBL, collaborative learning, inquiry-based learning, and cooperative learning. It is essential for programs not just to instruct teachers to utilize these approaches, but also to provide training as to how to utilize these approaches for specific subjects. Additionally, teacher-development programs should also provide teachers with lessons on the importance of creating a classroom climate that promotes student safety, value, and allows for authentic relationships to be formed with students.

There are also several implications for teacher-development programs regarding professional development for non-pre-service teachers. While professional development opportunities currently exist for STEM teachers, they do not typically address the strategies in increasing student interest in STEM subjects. As technology and the demands of the 21st-century continue to evolve, teachers should participate in professional development programs that focus on how to create meaningful content that relates to students' interests and engages students of all backgrounds.

Implications for disadvantaged and underrepresented minorities. The findings of this research study also highlight the importance of engaging students of all backgrounds, including those ethnically diverse and those from a low socioeconomic community. There is a vast majority of students from underserved populations, particularly Blacks, Hispanics, Native Americans, and those from low socioeconomic backgrounds, who are underrepresented in the STEM workforce (National Science Board, 2012). Diversity is an asset in all fields, and it should be a priority to provide students of all backgrounds access to qualified teachers, curriculum, and resources. Additionally, since the findings of this study offer knowledge on the instructional practices that promote STEM interest without the use of expensive resources, teachers in all communities can provide their students with access to quality STEM education. By adequately preparing a diverse group of students with the knowledge and skillsets demanded by the 21st-century workforce, teachers can influence students of all backgrounds to participate in STEM fields, helping diversify the STEM workforce.

Implications for STEM initiatives. Lastly, the findings of this research study have implications for STEM initiatives, particularly for policymakers and spear-headers in STEM education. Those with the power to modify the requirements for teacher-education programs, both at the administrative level and on a larger scale, should pay attention to the findings from RQ4. STEM teaching and learning requires a unique set of resources compared to other disciplines. Therefore, more attention should be placed on the following: (a) hiring teachers with the right set of skills, (b) providing teachers with sufficient curricular and financial resources, (c) integrating STEM disciplines together and with other subjects, and (d) creating more time for instruction and innovation.

Application

As a result of this study, a set of the best practices and strategies were identified regarding increasing student interest in STEM subjects. These practices and strategies were identified by interviewing exemplary teachers from institutions with distinguished STEM programs. The findings led to the development of Talar Gullapyan's Model for Increasing Student Interest in STEM Subjects (see Figure 12).

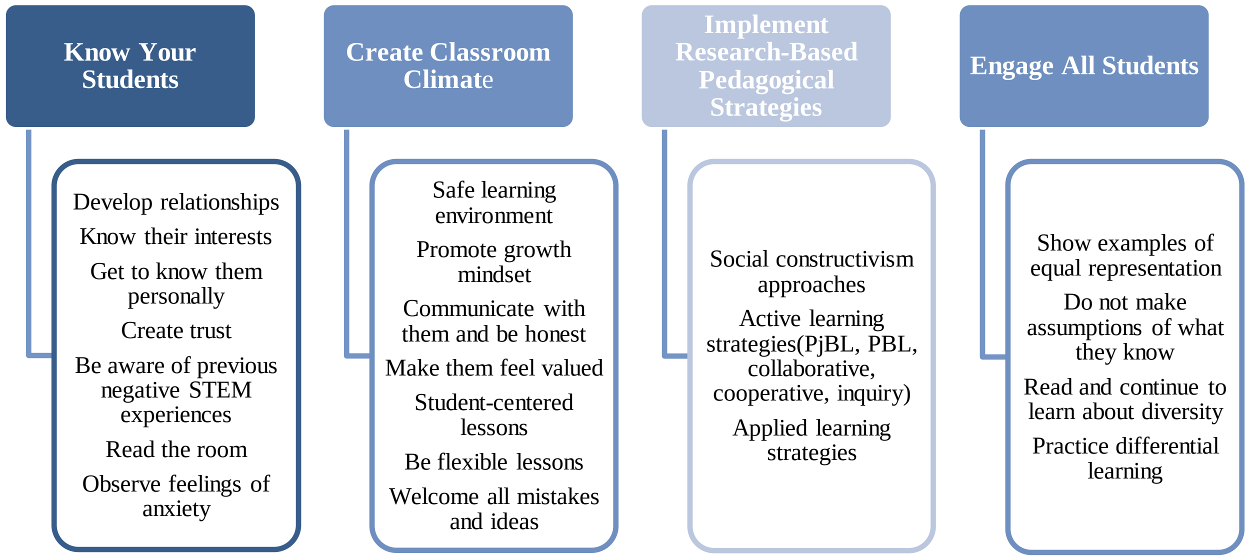

Figure 12. Talar Gullapyan's Model for Increasing Student Interest in STEM Subjects.

This model provides a foundation for K-12 teachers to increase student interest in STEM-related subjects, in no particular order. The first component, *know your students*, focuses on the importance of teachers relating with their students and forming personal relationships with them. This component is especially important with students who have had negative experiences in other STEM courses. The second component, *create classroom climate*, provides suggestions regarding creating an environment that promotes learning and engagement. The classroom climate should be one that is safe, promotes a growth mindset, allows for open communication between students and teachers, and is student-centered. The third component, *implement research-based instructional strategies*, provides teachers with the current instructional strategies that have proven to be effective in increasing student interest in STEM subjects. These strategies follow a social constructivist view on learning, which states that students learn best through social and cultural interactions and when they are actively engaged in the learning process. More so, social constructivist approaches include active learning strategies, such as PjBL, PBL, collaborative learning, cooperative learning, and inquiry-based learning. Lastly, the fourth component of the model, *engage all students*, focuses on providing students with equal access to STEM learning. It is integral for teachers to consider students and provide differential learning opportunities for students of all ethnic backgrounds and socioeconomic status. This model has practical applications that may be utilized by teachers, school administrators and policymakers.

Since educators from distinguished institutions may already be familiar with these practices, teachers from schools with less developed STEM programs would benefit most from these findings. These institutions include schools with an ethnically diverse student population and schools in a low socioeconomic community. To help educate teachers in these communities on the best practices and strategies to increase student interest in STEM subjects and to overcome challenges of time, student mindset, and curriculum, the researcher recommends an in-service training held during school hours. An exemplary teacher should lead the in-service training. Ideally, the teacher would be one who meets the criteria of inclusion for this study and is familiar with researched-based instructional strategies. Throughout the in-service training, the presenter should use the instructional practices they are recommending. Therefore, the in-service workshop should involve group discussions, active learning strategies, opportunities for an open dialogue, and should relate to teachers' reality. There should also be time and opportunities for the teachers to collaborate. Lastly, the presenter should try to get to know the teachers, make them feel valued, promote a growth mindset, and remember to use differentiated strategies to engage all participants.

Study Conclusion

Concerned with the low number of students in America entering the fields STEM and the low STEM literacy rate, the researcher began this study with the desire to contribute to the existing body of literature on the best practices to increase student interest in STEM-related disciplines. To accomplish this task, the researcher bracketed her personal biases and experiences on the strategies she has used to increase student interest in STEM subjects. After interviewing 12 STEM teachers who had experienced the phenomenon of student interest, the researcher coded and analyzed the results in response to 11 questions pertaining to student interest in STEM. The results informed four research questions that addressed the strategies, challenges, measures of success, and recommendations from K-12 teachers regarding STEM interest. As a result of this study and the findings from the literature review, the researcher developed an in-service training model regarding the best practices to increase student interest in STEM-related subjects.

Recommendations for Future Research

The purpose of this study was to identify the strategies and practices that K-12 teachers implement to promote interest in STEM subjects and STEM degree pursuance. This study also sought to identify the challenges K-12 teachers encounter when attempting to increase student interest in STEM subjects, how K-12 teachers measure the success of their practices, and the recommendations K-12 STEM teachers had for future implementation of strategies to increase STEM interest. In the process of answering these questions, opportunities for additional areas of research arose. To contribute to the existing body of literature on STEM interest, the researcher recommends the following as future areas for research:

1. A research study that answers the same research questions, but has a more narrow, specific unit of analysis. For instance, this study should be repeated for teachers only serving Kindergarten through fifth grade, sixth through eighth grade, and again for ninth through twelfth grade teachers. Since the literature on student interest suggests that

interest is developed during early education, more of an emphasis should be placed on elementary level education.

2. A study that is designed for a specific topic in STEM. Teachers of varying subjects have different approaches and strategies to increase student interest. Therefore, it would be helpful to identify the strategies specific to each subject.
3. Design a study for teachers and students that would assess students' perceptions of interest. This comparative analysis could determine if teachers are actually aware whether students are interested and engaged in the subject.
4. Future studies should also focus on the impact that positive student-teacher relationships can have on student outcomes for at-risk students.

Final Thoughts

As a STEM educator, the researcher genuinely enjoyed conducting this study. The literature review was eye-opening and enlightening. Most importantly, the participants provided insight from multiple perspectives that served to be an asset to this study. The diverse backgrounds, ethnicities, and levels of expertise from each participant provided rich data that was crucial to determining the best practices to increase student interest in STEM subjects.

Moving forward, it is the researcher's hope that educators, administrators, and policymakers continue to prioritize, emphasize, and improve STEM education in the U.S. The Nation's report card is concerning and should cause great worry and panic to all educators and employers. As the findings of this study suggests, classroom dynamics can determine students' attitudes and perceptions towards STEM subjects. Teachers can directly influence a child's level of understanding, feelings of their abilities, and career trajectory.

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APPENDIX A

IRB Approval Notice

PEPPERDINE

Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263
TEL: 310-506-4000

NOTICE OF APPROVAL FOR HUMAN RESEARCH

Date: January 13, 2020

Protocol Investigator Name: Talar Gullapyan

Protocol #: 19-09-1157

Project Title: Best teaching practices to increase student interest in STEM subjects

School: Graduate School of Education and Psychology

Dear Talar Gullapyan:

Thank you for submitting your application for exempt review to Pepperdine University's Institutional Review Board (IRB). We appreciate the work you have done on your proposal. The IRB has reviewed your submitted IRB application and all ancillary materials. Upon review, the IRB has determined that the above entitled project meets the requirements for exemption under the federal regulations 45 CFR 46.101 that govern the protections of human subjects.

Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit an amendment to the IRB. Since your study falls under exemption, there is no requirement for continuing IRB review of your project. Please be aware that changes to your protocol may prevent the research from qualifying for exemption from 45 CFR 46.101 and require submission of a new IRB application or other materials to the IRB.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite the best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the IRB as soon as possible. We will ask for a complete written explanation of the event and your written response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the IRB and documenting the adverse event can be found in the *Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual* at community.pepperdine.edu/irb.

Please refer to the protocol number denoted above in all communication or correspondence related to your application and this approval. Should you have additional questions or require clarification of the contents of this letter, please contact the IRB Office. On behalf of the IRB, I wish you success in this scholarly pursuit.

Sincerely,

Judy Ho, Ph.D., IRB Chair

cc: Mrs. Katy Carr, Assistant Provost for Research

APPENDIX B

Informed Consent

PEPPERDINE UNIVERSITY

(Graduate School of Education and Psychology)

INFORMED CONSENT FOR PARTICIPATION IN RESEARCH ACTIVITIES

Best Teaching Practices to Increase Student Interest in STEM Subjects

You are invited to participate in a research study conducted by Talar Gullapyan, M. S. at Pepperdine University because you are a K-12 STEM teacher with a minimum of three years of teaching experience. Your participation is voluntary. You should read the information below and ask any clarifying questions you may have before deciding whether to participate. Please take as much time as you need to read the consent form. You may also decide to discuss participation with your family or friends. If you decide to participate, you will be asked to sign this form. You will also be given a copy of this form for your records.

PURPOSE OF THE STUDY

The purpose of this study is to explore successful teaching strategies and practices used by K-12 teachers to increase student interest and degree pursuance in STEM-related disciplines. Specifically, this study's purpose is to determine the following:

- The successful strategies and practices K-12 teachers employ to increase student interest in STEM subjects.
- The challenges K-12 teachers face in increasing student interest in STEM subjects.
- How K-12 teachers measure success of their practices in increasing student interest in STEM subjects.
- The recommendations K-12 teachers would make for future implementation of strategies in increasing student interest in STEM subjects.

STUDY PROCEDURES

If you volunteer to participate in this study, you will be asked to participate in a semi-structured interview that will last for approximately 60 minutes, where you will be asked the following questions:

The semi-structured interview includes 10-12 open-ended questions that are designed in advance, with probes that are either planned or unplanned to clarify your responses. The interviews will be conducted in your place of work or in local meeting places. If you are not able to meet for an in-person interview, the interview can take place using a web-conferencing tool such as Zoom. During the interview, your answers will be audio- recorded. If you choose not to be audio-recorded, you will not be able to participate in this study.

POTENTIAL RISKS AND DISCOMFORTS

There are minor potential risks or discomforts associated with this study, including fatigue during the interview process.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR SOCIETY

While there are no direct benefits to the participant, there are several anticipated benefits to society which include:

- Students will experience an increased interest in STEM subjects.
- More students may choose to participate in STEM-related careers.
- Students will be better prepared with the skills needed to succeed in the 21st-century workforce.
- Teacher-education programs can incorporate the suggested strategies while training novice STEM teachers

CONFIDENTIALITY

The records for this study will be kept confidential as far as permitted by law. To guarantee confidentiality, pseudonyms will be used instead of your full name and school name. Throughout the study, you will be referred to as P1 through P15, resulting in no records that could personally identify you. The researcher will store all data in a secure database protected by a password that is only accessible by the researcher. Once the researcher transcribes the interviews, the recordings will be destroyed, along with any personally identifiable information. The data that are not destroyed, including transcriptions and all other non-identifiable data, will be kept in a secure location and destroyed after five years.

PARTICIPATION AND WITHDRAWAL

Your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may withdraw your consent at any time and discontinue without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study.

ALTERNATIVES TO FULL PARTICIPATION

The alternative to participation in the study is not participating or completing only the items which you feel comfortable.

EMERGENCY CARE AND COMPENSATION FOR INJURY

If you are injured as a direct result of research procedures you will receive medical treatment; however, you or your insurance will be responsible for the cost. Pepperdine University does not provide any monetary compensation for injury

RIGHTS OF RESEARCH PARTICIPANT

You may ask any questions concerning this research and have those questions answered before agreeing to participate in or during the study. For study questions and answers to inquiries, please contact at talar.gullapyan@pepperdine.edu. You may also contact Dr. Farzin Madjidi at Pepperdine University, 310-678-5600 or farzin.madjidi@pepperdine.edu if you have any other questions or concerns about this research. For IRB related questions, you may contact the university by email at gpsirb@pepperdine.edu.

DOCUMENTATION OF INFORMED CONSENT

You are voluntarily making a decision whether or not to participate in this research study. By signing the informed consent, your consent to participate is implied. You should print a copy for your records.

SIGNATURE OF RESEARCH PARTICIPANT

I have read the information provided above. I have been given a chance to ask questions. My questions have been answered to my satisfaction and I agree to participate in this study. I have been given a copy of this form.

Name of Participant ______________________________________

Signature of Participant ______________________________________ Date _______

SIGNATURE OF INVESTIGATOR

I have explained the research to the participants and answered all of his/her questions. In my judgment the participants are knowingly, willingly and intelligently agreeing to participate in this study. They have the legal capacity to give informed consent to participate in this research study and all of the various components. They also have been informed that participation is voluntary and that they may discontinue their participation in the study at any time, for any reason.

Name of Person Obtaining Consent ____________________________

Signature of Person Obtaining Consent ____________________________ Date _______

APPENDIX C

Recruitment Script

Dear [Name],

My name is Talar Gullapyan and I am a doctoral student in the Organizational Leadership program within the Graduate School of Education and Psychology at Pepperdine University. As part of fulfilling my degree requirements, I am conducting a study regarding the best practices and strategies to increase student interest in STEM subjects.

I found your name and email from the XYZ school website. As a result of your contributions to the field of STEM education, you have been carefully selected to participate. Participation in the study is voluntary and entails a 60-minute interview in person, or virtually via a Zoom session, at a convenient location near you (typically in your place of work). Confidentiality will be maintained throughout the study. The questions that will be asked in the interview and an Informed Consent Form will be sent to you in advance of the interview. Your participation will be extremely valuable to other teachers and students in order to increase student interest in STEM-related subjects and careers.

Thank you for your participation,

Talar Gullapyan
Pepperdine University
Graduate School of Education and Psychology
Status: Doctoral Student

APPENDIX D

Peer Reviewer Form

Dear reviewer:

Thank you for agreeing to participate in my research study. The table below is designed to ensure that may research questions for the study are properly addressed with corresponding interview questions.

In the table below, please review each research question and the corresponding interview questions. For each interview question, consider how well the interview question addresses the research question. If the interview question is directly relevant to the research question, please mark “Keep as stated.” If the interview question is irrelevant to the research question, please mark “Delete it.” Finally, if the interview question can be modified to best fit with the research question, please suggest your modifications in the space provided. You may also recommend additional interview questions you deem necessary.

Once you have completed your analysis, please return the completed form to me via email to talar.gullapyan@pepperdine.edu. Thank you again for your participation.

Research Question	Corresponding Interview Question
RQ1: What success strategies and practices do K-12 teachers employ to increase student interest in STEM subjects?	Icebreaker Q1: Can you tell me a little about your academic background and work experiences? **Keep as is.** Icebreaker Q2: Do you feel like your students are interested in the subject you teach? **Keep as is.** IQ 1: What pedagogies do you rely on when teaching your subject? **Keep as is.** IQ 2: What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students? **Keep as is, consider adding an additional question, such as:** IQ 3: How do you feel your academic background and professional training have prepared you to teach your subject?
RQ2: What challenges do K-12 teachers face in increasing student interest in STEM subjects?	IQ 4: What challenges do you face when teaching students with little interest in STEM subjects?

	Modify as suggested: What Is the most challenging part of teaching to students with little interest in STEM subjects, and how does it affect your teaching? IQ 5: Do you notice a difference when teaching students of minority groups? **Modify as suggested:** What unique differences do you notice when teaching to students of diverse backgrounds, including ethnic diversity and those from a low SES. IQ 6: What tools or resources are available or can be made available to help you overcome these challenges? **Keep as is.** IQ 7: To what extent have these challenges impacted your career path? .
RQ3: How do K-12 teachers measure the success of their practices in increasing student interest in STEM subjects?	IQ 7: What is your ultimate goal while teaching STEM subjects? **Keep as is.** IQ 8: How do you measure the success of your teaching practices? **Keep as is.** **Consider adding:** IQ: What behaviors do you believe indicate an increased interest in the subject matter?
RQ4: What recommendations would K-12 teachers make for future implementation of strategies in increasing student interest in STEM subjects?	IQ 9: How can novice teachers succeed in teaching STEM subjects to students with low STEM interest? **Modify as suggested:** What recommendations do you have for novice teachers to succeed in teaching students that are not interested in STEM subjects? IQ 10: What can academic leaders do differently to better support novice STEM teachers? **Keep as is.** IQ 11: Is there anything else you would like to add? **Keep as is.**

APPENDIX E

Final Interview Questions

- IQ1: What pedagogies do you rely on when teaching your subject?
- IQ2: What strategies (tools, techniques, philosophies) do you use to increase STEM interest in your students?
- IQ3: How do you feel your academic background and professional training have prepared you to teach your subject?
- IQ4: What is the most challenging part of teaching to students with little interest in STEM subjects, and how does it affect your teaching?
- IQ5: Are there tools or resources are available or can be made available to help you overcome these challenges?
- IQ6: Does teaching students of varying diverse backgrounds, including ethnically diverse and those from a low SES community, pose unique challenges for you. If so, how?
- IQ7: What is your ultimate goal while teaching STEM subjects?
- IQ8: How do you measure the success of your teaching practices?
- IQ9: What behaviors do you believe indicate an increased interest in the subject matter?
- IQ10: What recommendations do you have for novice teachers to succeed in teaching students that are not interested in STEM subjects?
- IQ11: What can academic leaders do differently to better support STEM teachers?
- IQ12: Is there anything else you would like to add?

APPENDIX F

CITI Completion

CITI PROGRAM

Completion Date 05-Apr-2018
Expiration Date 04-Apr-2021
Record ID 26561213

This is to certify that:

Talar Gullapyan

Has completed the following CITI Program course:

Not valid for renewal of certification through CME. Do not use for TransCelerate mutual recognition (see Completion Report).

Graduate & Professional Schools HSR	(Curriculum Group)
Graduate & Professional Schools - IRB Members and Reviewers	(Course Learner Group)
1 - Basic Course	(Stage)

Under requirements set by:

Pepperdine University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w80f269d1-a5a5-44f2-835b-70b8f2ca48cf-26561213