ABSTRACT

STEM Integration in Elementary Classrooms: A Quantitative Study Exploring Impediments and Improvements

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As the need for a STEM-literate workforce grows, educators must prepare to develop STEM-literate thinkers. American educators must modernize teaching practices and utilize the best research-based STEM pedagogy. STEM education can no longer be a novelty or supplement to classroom instruction, and this is especially true in elementary classrooms. Early exposure to STEM and the need for quality STEM instruction is imperative to capitalize on the innate curiosity and creativity of young learners. However, elementary educators are generalists and are not adequately trained to teach integrative STEM. Furthermore, state testing and lack of materials and funding make integrative STEM and other innovative teaching practices next to impossible. Elementary teachers need to be efficacious in STEM content and supported in integrating STEM instruction in their classrooms.

This quantitative study utilized a cross-sectional survey to identify the teaching self-efficacy of elementary educators in elementary classrooms and identify variables that might predict their STEM instruction. I used an online survey for data collection to
access a broad range of data, including teaching self-efficacy in mathematics and science, student technology use, STEM instruction, 21st-century learning attitudes, and interest in STEM-related professional development. Bandura’s self-efficacy theory was the theoretical framework used for this study. This theoretical framework asserts a teacher’s self-efficacy beliefs are related to the effort they invest in teaching, the goals they set for their students, and their perceived capability to learn new instructional strategies.

Based on the results of this study, participants’ self-efficacy in teaching mathematics and science has very little relationship with interest in STEM-related professional development. Collectively, mathematics teaching self-efficacy, science teaching self-efficacy, student technology use, and hours of STEM-related professional development are statistically significant predictors of a teacher’s STEM instruction score. Student technology use is the most prominent individual predictor of a teacher’s STEM instruction score. To bring about positive change in elementary STEM instruction, administrators must promote integrative STEM professional development, professional development leaders must make learning opportunities purposeful, classroom teachers must embrace integrative STEM instruction as a teaching method, and educators in preservice teacher programs must expose integrative STEM to aspiring teachers as often as possible.

**Keywords:** STEM, integrative STEM, elementary, teacher self-efficacy, 21st-century learning, professional development
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DEDICATION

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CHAPTER ONE

Background and Needs Assessment

Introduction

Innovation is the catalyst to progress, and America is losing its stronghold among developed countries in producing innovative leaders to address growing global issues (U.S. Department of Education et al., 2021). Science, technology, engineering, and mathematics (STEM) are among the most prominent paths to innovative practices (Ozfidan & de Miranda, 2017). Job growth in STEM industries is currently surpassing non–STEM industries by two-and-a-half times (U.S. Bureau of Labor Statistics, 2022). This poses a challenge considering that fewer than 40% of students who enter college with majors in STEM fields complete a STEM degree (Eagan et al., 2014). America’s highest-performing students are not scoring as well as their peers from other countries in mathematics and science (Kocabas et al., 2020; National Science Board [NSB]; 2022a). According to American Center for Education Statistics (2021), fourth-graders in America rank 15th in mathematics and 8th in science among the 64 most prosperous countries.

As the need for a STEM-literate workforce grows, educators must prepare to develop these STEM-literate thinkers. American educators must modernize teaching practices and utilize the best research-based STEM pedagogy (NSB, 2020). Limited research regarding the fundamental development of STEM knowledge among K–12 educators is available (Galanti & Holincheck, 2022). The purpose of this study was to identify the teaching self-efficacy of elementary educators in teaching science and mathematics, examine correlations between the teaching self-efficacy of elementary
educators in mathematics and science instruction with their interest in STEM-related professional development, and to identify variables that predicted how often elementary teachers reported incorporating integrated STEM in their classrooms. This study contributes to research regarding STEM in elementary classrooms and the certified educators tasked with sparking STEM interest and excitement in America’s future leaders.

Statement of the Problem

America’s economy needs innovative and creative thinkers, and America’s universities are not producing the quantity and caliber of workforce necessary to be competitive in the changing dynamic global market. Careers in STEM fields are projected to grow by 10% through 2031 compared to a 4% growth in overall employment in the United States (U.S. Bureau of Labor Statistics, 2022). Based on a 2022 NSB report, the United States has ceased to be a world leader in STEM, as indicated by three key indicators: STEM publications output, invention/innovation, and knowledge- and technology-intensive industry (KTI) activity (NSB, 2022a). China has surpassed the United States in STEM-related, peer-reviewed literature publications accounting for 23% of global publications compared to the United States with 16% (NSB, 2022a). During the same period, the U.S. share of international patents for inventions declined from 15% to 10%, while China’s contribution increased from 16% to 49% (NSB, 2022a). The same federal report maintains that the United States leads the world in KTI services, while China provides the greatest KTI manufacturing output globally. Foreign-born, college-educated workers are heeding the call for STEM-qualified professionals in the United States and currently account for one-fourth of the STEM workforce in this country (NSB,
2022a; U.S. Bureau of Labor Statistics, 2022). If American schools cannot meet the demand for STEM professionals, American companies will find them elsewhere.

Students begin exploring and considering career options early during their K–12 education. America’s limited STEM workforce originates in achievement, interest, and pursuit of challenging courses in high school and middle school (Schmidt & Shumow, 2014; Tai et al., 2006). Still, arguably, if students’ foundational STEM skills are low in elementary school, they will be less likely to enroll in those courses. Based on results among 10th-grade students on the Programme for International Student Assessment (PISA), American students consistently score below average in mathematics content and near or just above average in science objectives (The Organization for Economic Cooperation and Development [OECD], 2018). According to the 2019 Trends in International Mathematics and Science Study (TIMSS), mathematics and science achievement among American fourth-grade students has declined while students from comparable nations have remained steady or improved since 2011 (U.S. Department of Education et al., 2021). This data suggests deficiencies in the American education system and shows that countries with smaller economies and fewer resources produce a more competitive STEM workforce (Kocabas et al., 2020). Data from national reports highlight stagnant achievement in mathematics and science over the last 13 years (National Assessment of Educational Progress, 2019). While more American students are pursuing STEM degrees than in previous years, the more prominent growth is in the STEM degrees earned by foreign-born individuals. Almost half of all PhDs earned from American universities in STEM fields are awarded to international students (NSB, 2020).
These highly educated professionals contribute to research and development, but often not in the United States (NSB, 2022a).

Science and mathematics achievement during K–12 schooling indicates STEM pursuits beyond high school graduation, so elementary students must engage positively with STEM content. Student misperceptions of STEM lead many to lose interest and dismiss career aspirations in STEM fields (National Academy of Engineering [NAE] & National Research Council [NRC], 2014; Parker et al., 2020). The transmission model of teaching in which students are presented with isolated factual knowledge and tested on it (Saavedra & Opfer, 2012) no longer meets the needs of the global workforce expected to identify problems, collaborate with peers to find a solution, and effectively communicate ideas (Scott, 2015).

Students are less inclined to embrace STEM when they are not exposed to enough STEM instruction early in their education to explore their strengths, spark their interest, and develop positive attitudes (Archer et al., 2012; Dejarnette, 2012). Research by the Early Childhood STEM Working Group (2017) suggested that children are natural scientists and engineers. Still, they need the guidance and support of capable adults to foster their curiosity and guide their experiences.

Elementary educators must provide students with meaningful exposure to STEM disciplines. Still, teachers with low content self-efficacy can cause students to have low academic self-efficacy, poor scholastic achievement, and negative attitudes toward the content (Foley et al., 2017; Mayakis et al., 2018; Russo et al., 2020; Schmidt & Shumow, 2014). Most elementary teachers do not specialize in a specific content area as undergraduate students. When they do, few choose science. Sixty-four percent of
elementary educators graduate with fewer than three science courses completed, and STEM is rarely available as an option for specialization (Banilower et al., 2013; Bowers et al., 2020). A report by the National Council of Teacher Quality (NCTQ) found that just 12% of teacher preparation programs require courses or testing in two of the three primary science topics (biology, chemistry, physics), and two-thirds do not mandate a science course at all (Putman & Lubell, 2016).

Data is just as dire in mathematics, as 53% of elementary teachers have coursework in only one or two of the eight recommended mathematics content areas (Horizon Research, Inc., 2019). The report by NCTQ of teacher preparation programs found that only 13% address the necessary topics for teaching mathematics (Putman & Lubell, 2016). Most teacher training programs address general mathematics and science content, but few offer an explicit STEM block for elementary education. Relevant STEM teacher training must encompass mathematics and science content and pedagogy related to integrative STEM if in-service elementary teachers are to execute innovative teaching practices (Booher et al., 2020; Rinke et al., 2016).

Self-efficacy in teaching STEM content is a cause for concern as well. Teachers report feeling underprepared concerning interdisciplinary STEM content, and they say that they cannot integrate content at the elementary level (Dejarnette, 2012; Johnson et al., 2021; Stohlmann et al., 2012). Additionally, preservice teachers claim they are ill-equipped to teach integrative STEM or 21st-century skills as they begin their careers and instead teach in the same ways they were taught (Johnson et al., 2021). Preservice teachers “reported experiencing teacher-directed orientations growing up, focusing on lecturing and direct instruction” (Radloff & Guzey, 2016, p. 771), which is their default
teaching strategy. The exception is evidence that aspiring teachers demonstrated increased STEM teaching confidence, more complex content integration, and lesson planning that included using STEM literacies after participating in integrated STEM teacher preparation programs (Booher et al., 2020; Rinke et al., 2016). If teachers lack self-efficacy in teaching STEM content, their students will continue to lack STEM prowess compared to counterparts in competing nations.

The content and format of integrated STEM professional development offered to teachers fall short of meeting the needs of grades PreK–5 teachers to practically implement it. STEM professional development, particularly among elementary educators, is scarce (Guzey et al., 2016). Professional development regularly addresses reading and mathematics instruction despite teachers’ deficient self-efficacy around science and minimal science content knowledge (Brophy et al., 2008; Menon & Sadler, 2016). Even less professional development is offered in integrated instruction (Assessment Resource Center, 2016; Baker & Galanti, 2017; Kuehnert et al., 2019). In their systematic literature review, Margot and Kettler (2019) found that the “most often mentioned support that would increase the effectiveness of STEM education was learning opportunities for teachers to increase their ability to integrate STEM content into their curriculum effectively” (p. 14).

Furthermore, professional development, in general, must be purposeful to adult learners. A two-hour session focused on integrative STEM that is not reinforced nor revisited, for example, will not instill urgency for change (Hammack & Ivey, 2019; Havice et al., 2018). Best practices in andragogy suggest that learners must experience relevant and applicable learning in a comfortable environment in which they are active
learners and feel a sense of progress toward the learning goals and their own individual goals (Desimone & Garet, 2015; Knowles, 1996). Specifically, teacher professional development should be content-driven, collaborative, engaging, and meaningful, but this is often not the case given the constraints of time and resources (Baker & Galanti, 2017; Kennedy, 2016).

To positively impact the lagging STEM-literate workforce necessary in the competitive global marketplace, exposure to integrative STEM must begin in elementary classrooms (Banilower et al., 2013; Madden et al., 2016). In Northeast Independent School District (NEISD), which is the district that served as the site for this study, integrated STEM is not part of the elementary curriculum, and limited professional development opportunities are available for teachers interested in teaching STEM. Specific data is unavailable regarding teachers’ perceptions of their own teaching efficacy in STEM content areas, their integrative STEM instruction, and their engagement or interest in STEM professional development. Without this information, district leadership may not be able to develop a plan to meet the learning needs of teachers, much less students who will be competing for STEM jobs in the future.

**Literature Review**

STEM education is an essential element of the global economy. Educational research has revealed that elementary students in the United States are trailing their counterparts in other developed countries in science and mathematics (Banilower et al., 2013; National Research Council et al., 2009; U.S. Department of Education et al., 2021). Data suggests that early success in mathematics and science leads to STEM career pursuits; therefore, educators must possess the knowledge, skills, and tools to prepare
youth for the global economy (Hall & Rathbun, 2020; Tai et al., 2006). The challenge becomes equipping educators who lack background, self-efficacy, or training in STEM integration with opportunities to gain experience to become better STEM teachers.

Evidence from this literature review asserts that preparing the youth to be competitive in a global economy begins with integrating STEM education in elementary classrooms. The ensuing argument unfolds in five steps. First, in this literature review, I present the scholarship to demonstrate the need to establish and build STEM competencies and 21st-century skills among elementary students to prepare them to approach real-world problems analytically and creatively. Second, I share the many challenges to STEM education among elementary educators ranging from content self-efficacy to insufficient state learning standards. Third, I present literature surrounding predictors of integrative STEM at the elementary level. Fourth, I bring this literature into conversations with leaders in research-based best practices for STEM integration. Finally, I address the needs and interests of educators around professional development in STEM education.

*The Importance of STEM Education and 21st-Century Skills*

In education, the term *STEM* takes on different meanings and applications. Among peer-reviewed articles, STEM education is used to reference engineering education (Al Salami et al., 2017; Lachapelle & Cunningham, 2014), technology integration (Rich et al., 2017; Waterman et al., 2020), and science inquiry (Archer et al., 2012). Bybee (2013) discussed the various contexts in which the term *STEM* is used. *STEM careers* refer to any profession within the four separate categories. *STEM*
experiences are more of a general category encompassing any or all the components.

Regarding a sanctioned definition of STEM education, Bybee (2010) observed:

There is an interesting paradox I have observed concerning definitions in education: Many request a definition, and few agree with one when it is presented. So it is with STEM education. The meaning or significance of STEM is not clear and distinct. There is reference to four disciplines, but sometimes the meaning and emphasis only include one discipline. In some cases, the four disciplines are presumed to be separate but equal. Other definitions identify STEM education as an integration of the four disciplines. (p. x)

Some organizations go further and describe STEM education as interdisciplinary, multidisciplinary, or transdisciplinary.

In its position statement, the National Science Teaching Association (NSTA, 2020) described STEM education as “experiential learning pedagogy in which the application of knowledge and skills are integrated through in-context projects or problems focused on learning outcomes” (p. 1). STEM education provides real-world problem-solving opportunities. It also seamlessly provides problem-based learning scenarios that parallel those beyond the classroom (Akcanca, 2020; Holmlund et al., 2018). This understanding of STEM education aligns neatly with 21st-century skills, which are becoming more prevalent in global workspaces.

The demand for 21st-century skills is dictated by the shift from industrial social economies to the information- and knowledge-based social economies (Voogt & Roblin, 2012). Like STEM education, there is no universal understanding of 21st-century skills. Most literature discussing 21st-century skills include five categories of proficiencies, including communication skills, collaborative skills, individual learning approaches, individual autonomy, and information and communication technology (ICT) and digital literacy (Joynes et al., 2019; Scott, 2015; Voogt & Roblin, 2012). There is substantial
consensus that humans are no longer needed for jobs involving routine tasks that are now
done by computers, whereas jobs requiring interpretation of complex patterns and
analyses need a new set of human competencies (Joynes et al., 2019; Partnership for 21st-
century Skills, 2007; Scott, 2015). The benefits of developing 21st-century skills reach
far beyond job requirements.

Other literature consolidates 21st-century skills into a skillset called the 4Cs. The
4Cs are critical thinking, creativity, collaboration, and communication. These are deemed
the most crucial in the workforce by many who lament that these skills are lacking among
many current college graduates (Akcanca, 2020; NRC et al., 2009; NSB, 2010;
Partnership for 21st-century skills, 2007). The 4Cs are essential for young learners to
solve problems relevant to the world and adapt to the changing landscape of the
innovation (Seage & Türegün, 2019; van Ingen et al., 2018; Vasquez, 2015).

Benefits of and obstacles to teaching 21st-century skills. Schools are currently
struggling to meet the demands of the global economy. Bellanca asserted that “our
current public education system is not preparing all students for the economic, workforce,
and citizenship opportunities—and demands—of the 21st century” (2010, p. 5). The
author advocated for the implementation of a Framework for 21st Century Learning,
which focuses on skills beyond mere proficiency in core subject knowledge. This
sentiment has been shared by other scholars (Akcanca, 2020; Han et al., 2021; Joynes et
al., 2019). Joynes et al. (2019) emphasized the need for skills aligned with innovation and
creativity that are beneficial to a thriving nation. The NRC (2012) referred to these skills
as “21st-century competencies,” noting that they are a blend of applicable skills and their
incorporation with necessary content knowledge. Whether referred to as “skills” or
“competencies,” the consensus among researchers is that these abilities are indicative of the success of nations, organizations, and individuals and must be a priority of educators (Bellanca, 2010; Joynes et al., 2019; National Research Council, 2012; NSB, 2022a; Partnership for 21st-century Skills, 2007).

An additional benefit of teaching 21st-century skills in school is prepares a future workforce. America’s ability to create future leaders in STEM fields is contingent on preparing students with skills to think critically, collaborate, be creative, and effectively communicate ideas (Genek & Küçük, 2020; Madden et al., 2016; Seage & Türegün, 2019; van Ingen et al., 2018). Core content knowledge can be learned through 21st-century learning challenges that incorporate a broad range of skills that align with those necessary for a thriving economy (Joynes et al., 2019).

The combination of skills and content knowledge indicative of 21st-century competencies are incorporated throughout the Next Generation Science Standards (NGSS). The NGSS were developed to take K–12 learners beyond content knowledge to where content and practice intersect and 21st-century skills are essential elements of instruction (NRC, 2013). Two substantial obstacles impede the implementation of NGSS. First, not all states have adopted the NGSS, so they are not taught in all 50 states. Only 26 states participated in developing the standards, and their implementation is not federally mandated. The second challenge is preparing teachers to incorporate them. The NGSS integrates science, engineering, crosscutting concepts, and disciplinary core ideas (NRC, 2015). Teachers need time and support to transform the way they teach, but time and support are valuable, rare commodities.
Teachers value 21st-century skills and understand the need for students to acquire them early during their education (O’Neal et al., 2017; Saavedra & Opfer, 2012). However, they are often overwhelmed with other initiatives and lack the time to incorporate new standards or teaching practices. A report by the international OECD (2009) found that teachers are willing to attempt innovative practices but ultimately choose traditional practices aimed at efficiently transmitting knowledge in structured settings much more often than they use student-centered practices.

In elementary classrooms, technology is becoming a more prevalent tool for learning, but it is not being utilized to its full capabilities (Bencze, 2010; Deaton, 2015). The challenge is using technology to promote the development of 21st-century skills beyond word processing and Google searches. For example, proficiency in Information and Communication Technologies (ICTs), critical thinking, problem-solving, collaboration, communication, creativity, and leadership are 21st-century skills in high demand and must be introduced early in one’s education (Saavedra & Opfer, 2012).

Teachers cite external and internal barriers to teaching 21st-century skills. External barriers include access to reliable resources and inadequate leadership and support (O’Neal et al., 2017). Two-thirds of teachers in the United States report access to supplies and resources as a hindrance to their instruction (Educators for Excellence, 2022). Internal barriers consisted of a lack of time to develop or enhance a lesson, inadequate skills and knowledge in teaching 21st-century skills, and teacher beliefs about the importance of these competencies (Inan & Lowther, 2010; O’Neal et al., 2017). For elementary teachers to implement 21st-century skills into instruction, they must understand the value for students to attain these skills. Additionally, teachers must
understand 21st-century skills and how to implement them into their instruction. This is viable with adequate preparation in interdisciplinary teaching.

Benefits of elementary STEM. In addition to 21st-century skills, STEM education is an integral part of preparing our youth for education and careers that are becoming necessary. There is widespread agreement that innovative teaching practices prepare learners for future educational pursuits and real-life challenges (Akcanca, 2020, p. 21; Perry-Jenkins & Gerstel, 2020). Elementary and secondary STEM education is the foundation for future STEM majors and a wide array of STEM occupations (Rotermund & Burke, 2021). Researchers repeatedly highlight the importance of early exposure to STEM and the need for quality STEM instruction in elementary school (Akcanca, 2020; Bencze, 2010; Daugherty et al., 2014; Isabelle, 2017; Madden et al., 2016; National Academies of Sciences, Engineering, and Medicine, 2021; Prentiss Bennett, 2016).

Young learners possess an innate curiosity. This is prime for exploring, creating, and collaborating in STEM-related learning opportunities. Elementary school is the ideal opportunity to expose students to STEM and 21st-century learning. Studies report that students who actively engage in STEM early in their education are more likely to pursue STEM careers as adults (Douglas & Strobel, 2015; Madden et al., 2016; Toma & Greca, 2018). The organic sense of wonder among elementary students may be muted by mandated benchmark testing and curriculum compliance (Early Childhood STEM Working Group, 2017). Interest and curiosity in STEM concepts begin during K–5 instruction and continue through middle and high school (Archer et al., 2012; Dejarnette, 2012; Douglas & Strobel, 2015; NSB, 2010). STEM increases engagement, utilizes best practices for learning, and allows students to acquire academic content found in
educational standards while growing 21st-century skills necessary in pursuits of STEM fields (Dejarnette, 2012; Madden et al., 2016; Tai et al., 2006). STEM implementation in elementary classrooms is an opportunity for school systems to enhance learning with just a slight shift in instruction (Isabelle, 2017; NSB, 2010).

There are three primary benefits to engaging learners with STEM during K–5 instruction. First, STEM education easily aligns with best teaching practices, including problem-based learning, personalized instruction, and active learning (Akcanca, 2020; Bidarra & Rusman, 2017; Chan, 2008). Aligning early education with real-world experience begins with authentic learning opportunities. Problem-based learning requires the transdisciplinary application of skills and knowledge to achieve a goal (Rehmat, 2015). Students provide their own experience and background knowledge to build meaning and accomplish learning goals (Selcen Guzey et al., 2017), which are important to building 21st-century skills. One of the most crucial elements of 21st-century pedagogy is active learning (Bustamante et al., 2018; Dejarnette, 2012). Students must engage with content and peers; they need to interact, create models, and solve relevant, real-world problems (Baker & Galanti, 2017; Chan, 2008; Pinnell et al., 2013). Acquiring skills and knowledge is necessary but not the end goal. Applying the skills and knowledge in meaningful ways will prepare learners to persevere through more significant challenges in the future.

Second, an elementary school day provides creative structuring, allowing for easier STEM integration compared to rigid schedules in most grades 6–12 schools. Lack of flexibility in the instruction sequence and confines of class schedules are reasons cited by grades 6–12 teachers for not integrating STEM (Lesseig et al., 2016). Rather than
subjects taught in separate classrooms with different teachers, elementary instruction
mainly occurs in a single classroom where one teacher covers all content areas
(Daugherty et al., 2014). Elementary classrooms allow teachers more flexibility to
implement a STEM project in place of other individual assignments or easily integrate
activities into multiple content areas. Elementary students embrace a shift from the status
quo of a typical school day and are excited by the novelty of something new.

Third, young learners are primed for exploring and discovering, and STEM
education is an ideal opportunity to capitalize on their curiosity (Early Childhood STEM
Working Group, 2017; Hammack & Ivey, 2019). A strong positive relationship exists
between students’ science-related experiences during elementary school and the choice to
pursue STEM disciplines in high school and beyond (Dejarnette, 2012; Toma & Greca,
2018). Additionally, students in grades 2–4 who participated in an early STEM program
demonstrated a significant increase in scientific creativity compared to students with less
exposure to STEM instruction (Genek & Küçük, 2020). Students in elementary school
may not be deciding on college majors or career paths, but they are developing their
attitudes and perceptions of subjects and content so positive experiences are imperative
for future STEM pursuits (Dejarnette, 2012; Perdana et al., 2021).

*The case for integrative STEM education in elementary classrooms.* This
literature review argues the case for STEM education and 21st-century skills during
elementary education. The National Research Council (2009) explained STEM as more
significant than the sum of its parts. It concisely defined integrated STEM as a range of
experiences with some degree of connection. Some experts argue that defining integrative
STEM is not so simple (English, 2016; Roehrig et al., 2021). The scope of integrative
STEM is so vast, that after consulting with experts, researchers, and industry leaders, the committee charged with developing a national plan for improving integrative STEM in K–12 education was “unable to achieve a consensus on a concise and useful definition of integrated STEM education” (NAE & NRC, 2014, p. 23).

While unable to define integrated STEM education, the committee did develop an elaborate framework recommended to K–12 educational systems which includes goals, outcomes, the nature and scope and implementation of integrated STEM education. The framework provides various degrees of experiences and connections and allows for broad interpretation (see Figure 1.1). Integrative STEM, according to Sgro et al. (2020) is “whatever someone decides it means” and that the large variation across integrated STEM curricula suggests a need for “greater clarity about not only what constitutes STEM education, but how educators as a whole conceptualize STEM and the process of integration” (p. 185). For consistency, literature regarding integrative STEM, STEM education, and STEM instruction will be referred to integrative STEM moving forward.

To clearly discuss integrative STEM, there must be an understanding of what is integrative STEM. The framework provided by The National Academies Press in Figure 1.1 is extensive and provides valuable insight for a broad understanding of integrated STEM. The connection among content is key since there is a natural connectedness between mathematics, science, and STEM integration, allowing for exploration, discovery, and critical thinking (Baker & Galanti, 2017). Sanders (2009) indicated that “STEM education is business as usual, and integrative STEM education is interdisciplinary, multidisciplinary, and an alternative to teaching disconnected content” (p. 21).
A framework for K–12 integrated STEM education developed by Roehrig et al. (2021) included seven key characteristics: (a) focus on real-world problems, (b) centrality of engineering, (c) context integration, (d) content integration, (e) STEM practices, (f) 21st-century skills, and (g) informing students about STEM careers. These components of integrated STEM are applicable to a classroom teacher’s daily instruction. The framework is presented in Figure 1.2 and was the model for integrative STEM for this study.
Figure 1.2. Framework for K-12 integrated STEM education.


Challenges Elementary Teachers Face Regarding Integrated STEM Education

Taxing responsibilities beset elementary teachers, who may perceive integrated STEM as another initiative to occupy planning time and impede quality classroom instruction. Also, if national leaders and research experts are strained to define integrative STEM, elementary teachers are left to conceptualize an understanding on their own. Margot and Kettler (2019) compiled an index of studies focused on the challenges to STEM integration in elementary classrooms and found three significant obstacles to STEM integration. The obstacles include the need for STEM curriculum alignment with
state and district standards, logistical challenges such as time and resources, and prospects of student academic failure due to lack of teaching self-efficacy. Earlier, Brophy et al. (2008) had similar research findings, stating that teaching self-efficacy is a major hindrance to integrative STEM, which is often cited with other factors that interfere with integrative STEM in elementary classrooms.

In this section, I share the primary challenges interfering with STEM integration highlighted in the literature. First, I explore the misalignment of state learning standards with integrated STEM instruction (Al Salami et al., 2017; Margot & Kettler, 2019; Shernoff et al., 2017). Second, I share the lack of teaching self-efficacy among elementary teachers in science and mathematics content and its impact on students’ academic success (Donelley Smith, 2018; Han et al., 2021; Park et al., 2017; Stohlmann et al., 2012). Third, I address logistical challenges, including time and resources (Brophy et al., 2008; Park et al., 2017; Parker et al., 2015). I conclude the section by sharing a possible root of the problem, which is preservice programs that do not promote integrated STEM instruction (Johnson et al., 2021; Menon & Sadler, 2016).

**Challenge: State learning standards do not include integrated STEM instruction.**

Integrated STEM instruction is not present in most state education standards and even if it was included in state standards teachers often feel ill-prepared to teach what is a state standard. Only 39% of teachers in the United States report they receive the training necessary to implement curricula effectively (Educators for Excellence, 2022). As of 2021, 20 states and the District of Columbia have adopted the NGSS which integrates engineering and real-world contexts into science instruction (EdReports, 2021). Twenty-four other states have used the NGSS as a framework for their own standards.
In Texas, the NGSS do not provide a framework for instruction nor are there explicit STEM standards for elementary or middle school (Sedberry, 2021). A STEM education framework is available on the Texas Education Agency (TEA) website but does not explicitly align with any designated essential knowledge and skills for elementary or middle school instruction. TEA currently funds a K–8 Mobile STEM lab that visits approximately 50 (Sedberry, 2022) of the state’s 9,106 elementary and middle schools (TEA, 2022a) per year. Two full-time state staff members travel with the mobile lab and teach the STEM lessons. Aside from this mobile lab, few resources are available to support elementary STEM instruction or assist in the development of elementary teachers interested in integrating STEM.

The Texas Science Technology Engineering and Math Initiative developed by the TEA provides a blueprint for secondary STEM campuses interested in developing STEM-focused high schools. This is the state’s only set of guidelines to ensure fidelity for STEM campuses or programs and is designed exclusively for high school (TEA, 2022b). For three years, TEA (2022b) also provided a grant to high schools for the development or expansion of models that focus on developing or expanding STEM pathways in computer science or cybersecurity.

Challenge: Self-efficacy of generalist teachers in teaching mathematics and science. Above all other factors, teachers’ self-efficacy in teaching science and mathematics, content knowledge, and enthusiasm are the primary challenges to STEM integration in elementary schools (Buechel, 2021; Donnelley Smith, 2018; Fenton & Essler-Petty, 2019; Prentiss Bennett, 2016). Many studies have reported a positive correlation between self-efficacy in teaching mathematics and science and integrative
STEM instruction (Buechel, 2021; Donnelley Smith, 2018; Prentiss Bennett, 2016; Sloane, 2019). Han et al. (2021) utilized the T-STEM to reveal a significant direct effect of high school teacher self-efficacy on students’ STEM knowledge and achievement. Biscoe (2017) used the T-STEM to survey K–8 science teachers on factors that contribute to a positive teaching self-efficacy. Results indicated that no statistically significant relationship existed between science teaching self-efficacy and the factors investigated, including type of certification, time spent collaborating with peers, number of STEM professional development hours, and knowledge of STEM careers. Elementary teachers lack pedagogical expertise in scientific inquiry and often they lack the teaching self-efficacy to guide students through constructing their own knowledge and understandings (Bencze, 2010; Dejarnette, 2012; Menon & Sadler, 2016). Specifically, lack of teaching self-efficacy in integrative STEM increases their fears of student academic failures in STEM content areas (Margot & Kettler, 2019).

Science ranked as one of the least favorable and least enjoyable subjects to teach among in-service elementary teachers (Wilkins, 2009). A consequence to this is the quality of instruction for science and the time spent teaching it would likely be decreased compared to other subjects (Russo et al., 2020; Schmidt & Buchmann, 1983; Schraw & Olafson, 2003). Regarding mathematics, elementary teachers often opt for memorization and practice rote skills rather than the real-world application of mathematics content and skills (Baker & Galanti, 2017). Regardless of their favorability and teaching self-efficacy, states expect elementary teachers to teach all subjects effectively.

According to Bandura (1978), if teachers have low self-efficacy in teaching science, they are likely to avoid teaching science. Among preservice teachers, confidence
in teaching science is the product of exposure to science instructional practices and science content (Menon & Sadler, 2016; Velthuis et al., 2014). Preservice teachers reported feeling unprepared to teach science upon completing a teacher education program without science content embedded (Fenton & Essler-Petty, 2019; Mayakis et al., 2018), while preservice teachers who participated in a hands-on science content course reported higher self-efficacy in teaching science (Buechel, 2021; Menon & Sadler, 2016). This science content knowledge is imperative for the self-efficacy of preservice teachers and, ultimately, student achievement in science (Catalano et al., 2019). Self-efficacy in teaching science among practicing elementary teachers is not promising either (Abdullah et al., 2017; Catalano et al., 2019; Diamond et al., 2014).

Input from in-service elementary teachers regarding science was just as dire, considering priority is often placed on subjects with standardized assessments (Isabelle, 2017; Mayakis et al., 2018; van Ingen et al., 2018). There seems to be little acknowledgment or attention paid to the elementary teachers’ lack of teaching self-efficacy and science content knowledge. Science is only one of the four STEM disciplines, but many experts and trainers believe it is the easiest to integrate (Bustamante et al., 2018; National Research Council et al., 2009; Toma & Greca, 2018). Teachers with limited content knowledge and low teaching self-efficacy are not inclined to teach science, much less science combined with mathematics, engineering, and technology (Han et al., 2021; Isabelle, 2017; van Ingen et al., 2018). Han et al. (2021) reported a direct effect of teacher self-efficacy based on T-STEM data in students’ STEM knowledge and achievement reported on Student Efficacy and Attitudes Toward STEM (S-STEM) survey. Elementary teachers must develop interest and curiosity of their
students in STEM fields despite low teaching self-efficacy, sparse professional
development opportunities, and limited instructional time for science (Daugherty et al.,

Mathematics teaching self-efficacy is tied closely to one’s self-efficacy in
mathematics. Mathematics teaching efficacy is predicted by a teacher’s self-efficacy in
mathematics, therefore a teacher’s content knowledge and understanding of mathematics
is a key to student success (Bates et al., 2011; Perera & John, 2020; Zee & Koomen,
2016). A positive attitude toward teaching mathematics and positive views translate to
more in-depth teaching and learning based on student exploration and discovery (Briley,
2012; Stipek et al., 2001; Zee & Koomen, 2016). One’s mathematical beliefs
significantly affect mathematics self-efficacy and teaching efficacy, so beliefs in the
value of understanding and usefulness of mathematics in everyday life can shape an
elementary teacher’s mathematics instruction (Briley, 2012; Grouws, 1996).

**Challenge: Logistical challenges such as time and resources.** A major hindrance
to integrative STEM is access to resources and time constraints. According to a recent
survey by Educators for Excellence (2022), less than half of the educators who
participated reported that they have the materials they need for effective instruction. This
suggests that even when teachers see the value in STEM education, a lack of resources
still interferes with bringing STEM to students (Havice et al., 2018; Park et al., 2017).
Fiscal resources, including funding for instructional materials and quality professional
development, should be provided by districts and budgeted by state education officials
(National Academies of Sciences, Engineering, and Medicine, 2021). While STEM
education is often associated with computers and robots, which can be costly, it can be
accomplished with every-day, inexpensive items such as cardboard, string, paper clips, and recycled bottle caps (Clayton, 2019). STEM integration can be simple and cost efficient, but most teacher preparation programs do not expose preservice teachers in how to make it happen before stepping foot in an elementary classroom (Radloff & Guzey, 2016).

**Challenge: Teacher preservice programs focus on siloed courses.** To create a change in elementary classroom instruction, preservice teachers should engage in integrative STEM teaching practices. Most teacher preparation programs do not include integrative STEM courses (Daugherty et al., 2014; Radloff & Guzey, 2016) or teach integrative teaching methodology (Mcintyre et al., 2013; O’Brien, 2010; Rinke et al., 2016). Most preservice education programs offer separate methods courses in mathematics and science (O’Brien, 2010; Putman & Lubell, 2016). Most elementary teacher preparation programs only require one or two courses in each mathematics and science (Banilower et al., 2013; Horizon Research, Inc., 2019; Putman & Lubell, 2016). New teachers are earning certifications to teach all subject areas but are reporting low self-efficacy and confidence in teaching science and mathematics (Menon & Sadler, 2016; Radloff & Guzey, 2016). Technology integration is also not prioritized in teacher preparation programs, and engineering processes generally are absent in the syllabus or curriculum all together (Rich et al., 2017).

Teachers must learn to integrate STEM but teacher preparation programs are not making integrative STEM part of the curriculum for preservice teachers (Johnson et al., 2021). Among the few elementary preservice teacher programs that have STEM, there is growth in teachers’ STEM confidence, interdisciplinary content integration, science and
mathematics self-efficacy, and engineering design (Guzey et al., 2016; Madden et al., 2016; Rinke et al., 2016). Caliendo (2015) administered the T-STEM to two groups of preservice teachers before and after their clinical experiences. One group experienced STEM classrooms, and the other group experienced traditional classrooms. The group that experienced STEM classrooms reported an increase in science self-efficacy and a more positive attitude towards teaching STEM subjects than participants experiencing traditional classrooms (Caliendo, 2015). However, it seems these programs are few and far between. If state education authorities do not prioritize integrated STEM education, then preservice programs charged with preparing future teachers have little incentive to teach integrative STEM (Radloff & Guzey, 2016; Rinke et al., 2016), and future teachers have no incentive to integrate STEM into their instruction.

*Predictors of Integrative STEM Among Elementary Teachers*

Educators do not dispute the value of integrative STEM education for learners and there are predictors of integrative STEM teaching practices among classroom teachers. Galanti and Holincheck (2022) astutely observed that one’s STEM teaching practices are reflective of their identity as a STEM learner and STEM professional teacher, and these identities are formed based on how teachers position themselves or how they are positioned by others in professional development settings and classroom contexts. Longitudinal research examined correlations among participation in STEM professional development, integrative STEM implementation, and subsequent success and efficacy among students (Han et al., 2021; Kareem et al., 2022; Zee & Koomen, 2016). Based on current literature, there are three predictors of integrative STEM education. The first predictor of integrative STEM practice is teachers’ self-efficacy in STEM content areas
and one’s identity as a STEM learner and teacher (Chai et al., 2019; Galanti & Holincheck, 2022; Han et al., 2021). The second predictor is teachers’ participation in STEM-related professional development (Al Salami et al., 2017; Faber et al., 2013; Kelley & Knowles, 2016) and the third predictor is a teacher’s technology use for instruction (Abdullah et al., 2017; Chai et al., 2019; Kareem et al., 2022). Each predictor is examined in this section.

Self-efficacy in STEM content and one’s perceived identity as a STEM teacher has predicted a teacher’s integrative STEM teaching practices and was found to directly affect student academic achievement (Fenton & Essler-Petty, 2019; Han et al., 2021; Zee & Koomen, 2016). Teacher self-efficacy has implications for their classroom practices, collaboration, and professional development pursuits. Zee and Koomen (2016) reported that teachers with high self-efficacy collaborated more often with colleagues to improve data-driven decision making. Teacher with high self-efficacy also tend to perceive the implementation of new instructional practices as more important than less efficacious teachers. Fenton and Essler-Petty (2019) also concluded that increased self-efficacy positively impacted collaboration among teachers, as well as confidence in teaching integrative STEM lessons. Beyond the impact of teacher’s self-efficacy on their own confidence and practices, student self-efficacy, expectancy-value beliefs, and STEM academic achievement were significantly influenced by their teacher’s STEM self-efficacy (Han et al., 2021).

A teacher’s participation in STEM-related professional development has also proven to predict integrative STEM among elementary educators. Nadelson et al. (2013) explored the association between teacher preparation to teach STEM and student
achievement by creating a professional development program to address K-5 teacher confidence and attitudes toward teaching integrative STEM. Results from their pre- and post-institute survey showed a significant positive increase in the participants’ knowledge, self-efficacy, confidence, and attitude toward teaching STEM (Nadelson et al., 2013). Participants reported feeling better prepared to implement STEM and having increased knowledge and self-efficacy, comfort, and confidence in teaching STEM with this professional development structure. Faber et al. (2013) and Al Salami et al. (2017) reported similar findings in which teachers’ participation in STEM professional development positively impacted integrative STEM teaching practices. The T-STEM (Friday Institute for Educational Innovation, 2012b) was used by Faber et al. (2013) and highlighted a strong sense of confidence and overall self-efficacy among teachers who participated in a three-year STEM initiative, which also produced higher self-efficacy and outcome expectancies of students in STEM content areas.

A teacher’s integration of technology for instruction was found to predict integrative STEM practices. Chai et al. (2019) utilized the technological pedagogical knowledge (TPACK) framework to develop a survey used to assess teachers’ self-efficacies in content areas. They found that teachers’ willingness to integrate technology into instruction predicted their self-efficacy in integrative STEM. Similarly, Kareem et al. (2022) found a significant, direct effect of student technology use on student engagement in STEM education and 21st-century learning. In a study about teacher self-efficacy, Zee and Koomen (2016) found that teacher self-efficacy in technology was an important determinant to technology integration and other STEM teaching practices.
Best Practices for Integrating More STEM into Elementary Classrooms

Elementary students need more exposure to integrative STEM practices. The current challenge for educators is shifting away from their current teaching practices. STEM education is not a new idea as Sanders (2009) specifies integrated STEM education as an interdisciplinary concept rather than four separate subjects, and best practices for integrated STEM have evolved during this time. Studies and reports urging reform have propagated the necessity of this shift, but with little real change to practice (Milner–Bolotin, 2018). A dominant approach to education is the transmission model in which teachers transmit isolated factual knowledge to students that are later recalled during assessments (Saavedra & Opfer, 2012). This approach no longer meets the needs of the global workforce expected to identify problems, collaboratively determine possible solutions with a networked team, and articulately communicate orally and in writing (Scott, 2015). Many practices for improving integrated STEM instruction have been proposed and literature relating to three viable possibilities are shared in this section. The first practice is improved technology use. The second is integrative teaching, and the third is a blended learning model.

First, technology integration brings 21st-century skills and integrated STEM instruction to the forefront of elementary education (Akcanca, 2020; O’Neal et al., 2017). Information and communication technologies (ICT), collaboration, and critical thinking are developed with effective technology integration (Bencze, 2010; Gray et al., 2010; O’Neal et al., 2017). While technology may be available in elementary classrooms, innovative practices require more than having a laptop and internet access. When properly trained, teachers can utilize technology to greatly increase student engagement (Kareem et al., 2022). Technology use can be student-centered (Perdana et al., 2021;
Selcen Guzey et al., 2017), constructivist (Temiz & Topcu, 2013) and can be used for problem-based learning (Pearson et al., 2017) or multidisciplinary instruction (Doerschuk et al., 2016).

If teachers are not supported with professional development and pedagogical justifications to integrate technology effectively, they are unlikely to change their teaching practices (Bencze, 2010; Desimone & Garet, 2015). Adopting new practices with technology changes learning, teaching, and learning environments (Kareem et al., 2022; Wang & Lin, 2021; Waters, 2022). While these changes may bring about a positive outcome, barriers must be overcome for them to be enacted.

Second, integrative teaching allows students to explore engaging real-world content while learning and utilizing skills and knowledge from various academic content areas. Acquiring specific content knowledge is essential. That noted, exclusively separating discipline knowledge and processes do not reflect real-world scenarios; therefore, an interdisciplinary approach to teaching would most benefit learners (Parker et al., 2015; Smith et al., 2018). There is a natural connectedness between academic content and STEM integration, allowing exploration, discovery, and critical thinking (Baker & Galanti, 2017). Consistent themes across various models of integrative teaching include meaningful and engaging content, collaboration among peers, student-centered activities, and skills and knowledge from two or more STEM content areas (Kelley & Knowles, 2016; Pinnell et al., 2013; Sanders, 2009; Stohlmann et al., 2012; Wang et al., 2011).

Third, blended learning consists of hands-on activities in the classroom in addition to asynchronous components such as virtual labs and educational games (Seage & Türegün, 2019). Elementary educators cite a plethora of challenges to integrating
STEM into their instruction, not least of which is limited available instructional time (Stohlmann et al., 2012). One solution to instructional time constraints is blended learning. Blended learning might include in-class small group instruction, learning centers, digital storytelling or gamification, or virtual learning (Bidarra & Rusman, 2017). Learners are engaged in self-paced experiences and small group instruction during traditional class times while asynchronous learning can happen anytime from anywhere. Seage and Türegün (2019) implemented a model in which some elementary students were exposed to integrated STEM using a traditional 5-E model, and some learned integrative STEM using a blended learning model. Results indicated that students placed in a blended learning environment scored higher on tests measuring science, engineering, and technology and a separate test that measured mathematics achievement.

Evidence supports the use of blended learning models to make integrative STEM education more attainable and improve academic achievement while also allowing for student autonomy (Bidarra & Rusman, 2017). Students in grades 3–12 embraced blended learning for several reasons, including working at their own pace, developing creativity skills, opportunities to collaborate with peers, and mastering content in a way that fits their learning styles (Project Tomorrow, 2015). Students were enthusiastic about blended learning, and it reaped positive results in academic achievement. Teachers benefited from professional development in blended learning as an avenue to STEM integration. These improvements in teaching are feasible with meaningful, appropriate teacher professional development.

Bidarra and Rusman (2017) proposed a blended learning model described as participatory and interactive. This model brings together many best practices for
integrating STEM as it involves technology use and integrative learning. Their model is referred to as Science Learning Activities Model (SLAM) and incorporates a variety of science learning contexts, technology integration methods, and pedagogical models taking place synchronously and asynchronously at school and outside of school (Bidarra & Rusman, 2017).

**STEM Education Professional Development**

High–quality professional development elicits changes in instruction among elementary teachers. Milner-Bolotin (2018) proposed supporting classroom teachers through effective professional development as a possible solution to previous lackluster efforts to increase STEM literacy. By focusing professional development on STEM education, teacher self-efficacy can improve, increasing time spent teaching quality STEM in the classroom (Darling–Hammond, 2000). The foundation for effective STEM professional development begins with the fundamentals of effective professional development.

*Characteristics of effective professional development.* Professional development for educators varies in format, length, and content. There is a wealth of literature on professional development best practices for teachers (Assessment Resource Center, 2016; Banilower et al., 2007; Desimone & Garet, 2015; Eun, 2008; Flint et al., 2011). Consistent themes from these sources regarding effective professional development suggest it: (a) aligns with curriculum and needs of students, (b) is focused on content and how students learn content, (c) includes groups of teachers who collaborate and, (d) involves active learning. However, best practices are inevitably situation–dependent, learner-driven, and assessment is often subjective (Merriam & Bierema, 2014).
The first element of best practices applies to the substance of professional development, ensuring it aligns with state standards and the needs of students. Teachers must have a compelling reason to adhere to new teaching practices. Learning the required new curriculum along with relevant classroom lessons is more likely to result in successful content integration (Desimone & Garet, 2015). Teachers must explicitly understand the link between the professional development content and the actions required to improve student learning (Desimone & Garet, 2015). Learning outcomes are arguably the most important measure of effective professional development (Guskey, 2002). Adult learners need to know that what they are learning applies to their students and will be ready to learn to apply new strategies in their classrooms.

The second consideration for professional development best practices relates to content and how adults learn content. According to Knowles’s (1996) principle of andragogy called readiness to learn, adults learn best when the topic is timely and relevant to learners. Second, Knowles’s (1996) orientation to learning assumption posits that adults learning is more problem-centered than subject centered. Real-world problems create meaningful opportunities to apply one’s experience to find solutions. Ormrod (2020) called these authentic activities and deems them relevant to all human learners. This foundation of adult learning (Mezirow, 2000) syncs with essential 21st-century skills (National Research Council, 2012; Partnership for 21st-century Skills, 2007). Meaningful professional learning is timely and relevant to learners.

The third element of effective adult learning is collaboration. Learning alongside a team is another best practice for professional development (Rockland et al., 2010). Literature has long established that working with peers is key to effective professional
Collaboration among peers allows adults to relate learned concepts to daily lived experiences. Additionally, collaboration among heterogeneous groups allows for different perspectives and insights (Estapa & Tank, 2017).

Active learning is the fourth best practice for professional development. Rather than sitting through a lecture, active learning is effective, engaging, and purposeful (Darling–Hammond & Richardson, 2009). Instructional coaching, peer observation, and discussion groups are examples of active learning. When teachers are provided opportunities to practice what they are expected to teach and watch other professionals model teaching, their learning becomes more meaningful (Desimone & Pak, 2017).

When properly aligned, teacher-trainers can use best professional development practices that teachers can utilize in their own classrooms when teaching integrated STEM. Key best practices of both professional development and pedagogy include learning that is meaningful, active, and collaborative. These elements are also essential to integrative STEM instruction (Bybee, 2010, 2013), which is multidisciplinary. In the following subsection, I share these elements that professional development leaders can model, which can later be applied to integrated STEM classroom instruction.

*Modeling integrative STEM during professional development.* Leaders of professional development can model the characteristics of integrative STEM while teaching about integrative STEM. Professional development that is multidisciplinary, meaningful, collaborative, and includes active learning is more likely to elicit a change in STEM teaching practices and subsequently, student learning (Desimone & Garet, 2015)
First, integrative STEM education is multidisciplinary at its essence and uses content knowledge and skills to explore and understand real-world issues. In elementary classrooms, problem-based learning, such as integrative STEM, mimics this process design of inquiry requiring learners to think critically and engage in higher-order thinking to find solutions (Akcanca, 2020; Rehmat, 2015). Students still need content knowledge, but it will be learned in a timely, applicable manner with the support of classroom teachers (Early Childhood STEM Working Group, 2017). Professional development leaders can accomplish this by offering professional development that combines learning standards from multiple content areas. If classroom teachers learn STEM instructional practices in practical, applicable ways, their learning can transfer directly to their classrooms.

Second, learning must be meaningful. For adults, real-world problems are organic, and a person’s orientation to learn deems it necessary to figure out a solution (Knowles, 1972). This adult orientation to learn is congruent to problem-solving in STEM subjects and integrative STEM in elementary classrooms (Nelken, 2009; Rehmat, 2015; Waters & Orange, 2022). Integrated STEM learning prepares children for real-world situations in a safe, supportive setting (Kelley & Knowles, 2016; Stohlmann et al., 2012). Professional development leaders can provide opportunities for educators to experience problem-solving, which teachers can implement in their classrooms.

Active learning is the third essential element and is more than bodily movements, although embodiment is a powerful cognitive tool (Ormrod, 2020). Recent studies encourage hands-on learning such as integrative STEM (Akcanca, 2020; Bustamante et al., 2018) and culturally relevant pedagogy. Examples of hands-on learning in elementary
classrooms include engineering projects, science explorations, and math investigations. Professional development leaders might model integrative STEM lessons that allow experiential learning for teachers.

Collaboration allows for distributed cognition in which a group of learners shares the learning experience among their various knowledge bases and experiences (Ormrod, 2020). This is true for all learners but arguably more important for young learners, each with a narrower background of experiences than most adults. Collaboration also allows children to communicate ideas to peers, learn to respect others, appreciate the opinions of others, and succeed in the 21st-century (Partnership for 21st-century Skills, 2007). These are skills necessary to function in society as adults, and children can develop these with the support and guidance of a teacher. Collaborative learning promotes learning among elementary educators during integrated STEM professional development (Nadelson et al., 2013; Parker et al., 2015; Sias et al., 2017). Similar to group learning activities in elementary classrooms, professional development leaders can create opportunities for teachers to share a learning experience.

In summary, when done properly, teachers can learn about integrative STEM and how to teach integrative STEM in applicable ways when andragogy and pedagogy are aligned. Effective integrative STEM professional development can positively affect the instruction of elementary educators and provide models for best practices applicable in classrooms. Professional development programs focused on integrative STEM education have been developed and enacted with promising results, but they are few and far between (Baker & Galanti, 2017; Estapa & Tank, 2017; Havice et al., 2018; Nadelson et al., 2013). While children’s experiences are not as extensive as those of most adults,
cultural and societal experiences help in making sense of the world (Holmlund et al., 2018; Partnership for 21st-century Skills, 2007).

**STEM professional development interests of elementary teachers.** According to the results of the Missouri K–12 STEM Teachers Professional Development Survey (MO-STEM) by the Assessment Resource Center at the University of Missouri (2016), educators valued accessing ready-to-use materials, learning from other teachers, and learning about new and innovative teaching strategies. This was particularly true among elementary teachers (Assessment Resource Center, 2016). Among these participants of the MO-STEM survey, using real-world issues in the classroom was perceived to be the most important topic, and teachers also reported the highest level of interest in attending professional development about mathematical practices and aligning instruction and curriculum with standards (Assessment Resource Center, 2016). These results were consistent with the results of Owens (2018) study of teachers’ views of professional development interests in STEM. Interestingly, Nesmith and Cooper (2019) found that in-service teachers were highly interested in learning more about engineering design practices after participating in a two-year long afterschool STEM professional development program. This greatly contrasted the findings of Owens (2018) and the Assessment Resource Center (2016), which each ranked engineering practices as one of the bottom two interests among participants in the MO-STEM survey.

**Synthesis of Literature**

This literature review highlighted the need for a STEM-literate workforce for global prosperity and the benefits of integrative STEM in elementary classrooms. STEM education has been a proposed solution for better preparing young Americans to excel
globally (Akcanca, 2020; Bencze, 2010; Daugherty et al., 2014; Isabelle, 2017; Prentiss Bennett, 2016; Rotermund & Burke, 2021). Exposure to STEM must begin early in a child’s education, so there is adequate time to build a foundation of STEM knowledge and interest (Dejarnette, 2012; Early Childhood STEM Working Group, 2017). Students must also acquire the necessary skills to succeed in the evolving global workspace. Young learners in grades K–5 are primed for exploration and problem solving that lays the foundation for how they approach learning and thinking for the rest of their lives (Early Childhood STEM Working Group, 2017; Lange et al., 2021; Will, 2018).

Standardized tests do not assess critical thinking, creativity, 21st-century skills, analyzing abstract concepts, and many important process skills (Akcanca, 2020; Partnership for 21st-century Skills, 2007). State agencies, districts, campuses, and educators continue to prioritize content that is tested.

Studies consistently report prominent challenges to integrative STEM in elementary classrooms. Responsibility for creating these learning opportunities fall on the shoulders of classroom teachers, but teachers experience many barriers to implementing integrative STEM. The most significant barrier is that teachers are not adequately trained in aligning current state learning standards with STEM content or pedagogy (Clayton, 2019; Lange et al., 2021; Rotermund & Burke, 2021). Furthermore, most elementary teachers lack self-efficacy in STEM content (Briley, 2012; Catalano et al., 2019; Fenton & Essler–Petty, 2019; Perera & John, 2020; Rinke et al., 2016) and feel ill-prepared to teach integrated STEM (Estapa & Tank, 2017; Galanti & Holincheck, 2022; Sgro et al., 2020). Also, access to resources and funding is a debilitating challenge to integrative STEM in elementary schools (Ejiwale, 2013; Hammack & Ivey, 2019). Not surprisingly,
Preservice teachers reported not feeling prepared by university courses in mathematics and science to teach the same content or integrate it for elementary students (Bustamante et al., 2018; Clayton, 2019; Johnson et al., 2021). While universities struggle to prepare preservice teachers to meet the challenges of the evolving classroom (Fenton & Essler–Petty, 2019; Madden et al., 2016), state and district officials delay changing the way teachers teach to address the shifting demands of the global workspace (Abdullah et al., 2017; National Academies of Sciences, Engineering, and Medicine, 2021; NSB, 2022a).

While pressing challenges exist, integrative STEM does occur in some elementary classrooms, and literature has highlighted predictors of STEM teaching practices. The three primary predictors of integrative STEM practice discussed in this literature review are teachers’ self-efficacy in STEM content areas and one’s identity as a STEM learner and teacher (Chai et al., 2019; Galanti & Holincheck, 2022; Han et al., 2021), teachers’ participation in STEM-related professional development (Al Salami et al., 2017; Faber et al., 2013; Kelley & Knowles, 2016), and teacher’s technology use for instruction (Abdullah et al., 2017; Chai et al., 2019; Kareem et al., 2022). Substantial research aligns these practices with self-efficacy in innovative teaching and integrative STEM.

If instructional leaders prepare teachers in innovative approaches, then teachers are more inclined to use innovative methods to meet the needs of their students (Tondeur et al., 2017; Waters & Orange, 2022). Preparing teachers to effectively use technology for instruction, use integrative teaching strategies, or blended learning models are other ways to prepare students to be successful (Akcanca, 2020; Bidarra & Rusman, 2017; Rehmat, 2015; Seage & Türegün, 2019). Integrative STEM instruction supports each of these best teaching practices.
STEM integration begins with preparedness in content areas but if elementary educators report having low self-efficacy in science and mathematics, professional development should address this deficit (Catalano et al., 2019; Donnelley Smith, 2018; Sloane, 2019). Therefore, professional development planners must consider teachers’ learning needs for STEM integration, areas in which they lack self-efficacy, and best practices for teaching (Banilower et al., 2007; Desimone & Garet, 2015; Owens et al., 2018). Additionally, teachers report interest in learning how to teach through real-world issues and problem-based learning, so professional development should attend to the interests of the learners (Assessment Resource Center, 2016; Owens et al., 2018). Professional development leaders should model teaching integrative STEM considering its similarities with problem-based learning and its application to real-world problems.

The literature review summarizes best practices for integrating STEM and best practices for professional development. Prior research falls short of gathering data on professional development practices and teacher self-efficacy, STEM integration, and interests. There is a significant need for a study to understand elementary teacher self-efficacy for teaching STEM, the implementation of STEM instruction, and the subsequent pursuit of professional development. As such, I designed this study to identify the teaching self-efficacy of elementary educators in Northeast Independent School District (NEISD) elementary classrooms and identifying variables that might predict their STEM instruction.

**Theoretical Framework**

The framework that guides this study is Bandura’s theory of self-efficacy. Bandura (1978) explained the concept of self-efficacy as an assessment of one’s
capabilities to attain a desired level of performance in a given endeavor. This belief in one’s abilities is a powerful driving force to act, put forth effort, and persevere in the face of adversity. Self-efficacy is a component of the reciprocal triad, including personal, behavioral, and environmental factors, which Bandura (1978) contended interact and influence one another as part of the social cognitive learning theory.

Bandura postulated that teacher self-efficacy “rests on much more than the ability to transmit subject matter” and impacts more than instruction, namely, “maintaining an orderly classroom conducive to learning, enlisting resources and parental involvement in children’s academic activities, and counteracting social influences that subvert students’ commitments to academic pursuits” (Bandura, 1997, p. 243). A low sense of instructional efficacy among teachers resulted in more student misbehaviors, less student improvement, and more intrinsic stress and anger (Bandura, 1997). Bandura indicated that teachers’ self-efficacy beliefs are related to their persistence when teaching difficult content areas, the effort that teachers invest in learning and teaching, and the goals they set for their students (Tschannen-Moran et al., 1998). Each of these components is critical to Bandura’s theory of teaching self-efficacy.

Teaching self-efficacy influences teachers’ willingness to learn innovative teaching strategies and their own learning self-efficacy. Self-efficacy for learning is specific to one’s perceived capability to learn new skills, techniques, and behaviors (Bandura, 1990; Schunk & DiBenedetto, 2016). Individuals with higher self-efficacy are more inclined to embrace change as an opportunity for growth (Bandura, 1997). Regarding 21st-century learning and integrative STEM, teachers’ self-efficacy can impact their willingness to try innovative teaching practices. Based on the self-efficacy
theory, learners who do not expect to be successful will likely put forth less effort and give up easily at the first sign of difficulty (Tschannen–Moran & Hoy, 2007). Suppose teachers are not self-efficacious in their learning and adaptability of content and skills. In that case, it will also negatively impact students’ learning because “technologies change rapidly, requiring continual upgrading of knowledge and skills. Teachers’ beliefs in their efficacy affect their receptivity to, and adoption of, educational technology” (Bandura, 1997, p. 241).

Previous studies have utilized Bandura’s self-efficacy theory to examine the relationship between teacher efficacy in content areas and student academic achievement. Teacher self-efficacy in content areas has proven to relate positively to student motivation and achievement (Ashton, 1984; Perera & John, 2020; Zee & Koomen, 2016). Bandura (1997) described how the self-efficacy of teachers can have broad implications on student experiences and success in the classroom:

- The task of creating learning environments conducive to development of cognitive competencies rests heavily on the talents and self-efficacy of teachers. Evidence indicates that teachers’ beliefs in their instructional efficacy partly determine how they structure academic activities in their classrooms and shape students’ evaluations of their intellectual capabilities. (p. 240)

This understanding of teacher self-efficacy indicates that students’ development in cognitive competencies is deeply impacted by a teacher’s self-efficacy (Zee & Koomen, 2016). Teachers’ beliefs about their instructional efficacy can be measured by their students’ mathematics and language achievement, students’ academic interest, and their motivation (Bandura, 1997). Student development depends not only on teachers’ content knowledge but also on how they teach, interact with students, and support student learning.
Clear benefits accompany a high sense of teaching self-efficacy, but some critics report that Bandura’s (1997) theory falls short of exploring specific aspects of self-efficacy beliefs among teachers. Bandura reported on the consequences of teaching self-efficacy but does little to highlight the sources of the self-efficacy (Tschannen-Moran & Hoy, 2007; Zee & Koomen, 2016). Much of the proceeding research based on Bandura’s (1997) self-efficacy theory also contained flaws in methodology and measurement (Klassen et al., 2011; Morris et al., 2017). After consulting 218 empirical articles, Klassen et al. (2011) found measurement and conceptual problems (Caprara et al., 2006; Tschannen-Moran & Hoy, 2001), a lack of attention to the sources of teacher efficacy (Henson, 2002a; Milner & Hoy, 2003; Tschannen-Moran et al., 1998), a lack of evidence that linked teacher efficacy with student outcomes (Pajares & Miller, 1994; Tschannen-Moran et al., 1998), and the relationship between teacher efficacy research to educational practice was uncertain at best (Wheatley, 2005). Morris et al. (2017) similarly reviewed literature regarding the sources of teaching self-efficacy. They concluded that shortcomings in the theory and methodologies present among the 82 studies prevented a clear understanding of how teachers develop beliefs in their efficacy. While critics highlight the shortcomings of Bandura’s (1997) theory of teaching self-efficacy, it is still best suited for the current study. The current study seeks to collect data on teaching self-efficacy as a predictor variable and how it might impact STEM instruction and other factors, which is not an identified flaw of the theory.

**Conclusion: Purpose of the Study and Research Questions**

The purpose of this quantitative correlational cross-sectional survey research was trifold. The first purpose of this survey was to examine correlations between teaching
self-efficacy of elementary educators in mathematics and science instruction with their interest in STEM-related professional development. The second purpose was to understand their attitudes about 21st-century learning skills and their integrative STEM teaching practices. The third purpose was to examine if elementary teachers’ reported teaching self-efficacy, technology use, and hours of STEM professional predicted how often they incorporate integrated STEM in their classrooms. The following research questions guided the study:

1. What are NEISD elementary teachers’ self-efficacy in teaching mathematics and science, and how does this teaching self-efficacy correlate with their interest in STEM-related professional development topics?

2. What are NEISD elementary teachers’ attitudes about 21st-century skills and how often do they report implementing integrative STEM?

3. Do hours of STEM-related professional development, science and mathematics teaching self-efficacy, and technology use predict elementary teachers’ STEM instruction scores?

The results of this study inform the district and elementary school leadership, professional development leaders, classroom teachers, and educators in preservice teacher programs. Effective professional development in STEM integration and its content areas provides elementary educators with knowledge, strategies, and self-efficacy to engage young learners, build positive attitudes toward STEM, and potentially pique curiosity and interest among students. In acquiring these skills and knowledge, elementary educators can prepare students to solve global problems with innovative approaches. The following chapter details the cross-sectional survey research design and the methodology applied to the study.
CHAPTER TWO

Methodology

Introduction: Research Questions

Elementary teachers in America have been shown to be less efficacious in mathematics and science, which hinders their ability to teach those subjects effectively and adequately prepare our future leaders in STEM (Donnelley Smith, 2018; Fenton & Essler–Petty, 2019; Prentiss Bennett, 2016). The current study focused on identifying the teaching self-efficacy of elementary educators in Northeast Independent School District (NEISD) elementary classrooms and identifying variables that might predict their STEM instruction. The research questions guiding the correlational cross-sectional survey research addressed the self-efficacy of elementary teachers in mathematics and science teaching, integrative STEM education in elementary classrooms, student technology use, and teacher attitudes about 21st-century learning in NEISD. Three research questions informed this study:

1. What are NEISD elementary teachers’ self-efficacy in teaching mathematics and science, and how does this teaching self-efficacy correlate with their interest in STEM-related professional development topics?

   H₀: No statistically significant correlation exists between NEISD elementary teachers’ teaching self-efficacy in mathematics and teaching self-efficacy in science with their interest in STEM-related professional development.

   H₁: A statistically significant correlation exists between NEISD elementary teachers’ teaching self-efficacy in mathematics and teaching self-efficacy in science with their interest in STEM-related professional development.
2. What are NEISD elementary teachers’ attitudes about 21st-century skills, and how often do they report implementing integrative STEM?

3. Do hours of STEM-related professional development, science, and mathematics teaching self-efficacy, and technology use predict elementary teachers’ STEM instruction scores?

\[ H_0: \] Elementary teachers’ hours of STEM-related professional development in the past year, science teaching efficacy, mathematics teaching efficacy, and student technology use do not statistically significantly predict their STEM instruction score.

\[ H_1: \] Elementary teachers’ hours of STEM-related professional development in the past year, science teaching efficacy, mathematics teaching efficacy, and student technology use statistically significantly predict their STEM instruction score.

Researcher Perspective and Positionality

My perspective, relationship to the research focus, and connection to the study’s participants and site location are relevant to the study. At the time of the study, I was an elementary teacher at NEISD. As an employee, I had existing relationships with teacher participants in the study. My perspective is one of curiosity concerning STEM education in elementary classrooms. I was a campus leader, served as a campus mathematics point-of-contact in the district, and worked to align state science standards, the Texas Essential Knowledge and Skills (TEKS), across grade levels. I earned the designation of an Inspiring Innovator. My primary role was regularly collaborating with district leadership to implement innovative teaching practices before district technology leadership pushed them out to my colleagues. I also participated in a six–month STEM education cohort with educators from the San Antonio area.

I encountered elementary teachers resistant to STEM and technology integration despite acknowledging the benefits and long–term positive implications. Teachers discuss the lack of time and resources as reasons for not integrating STEM. Still, few are open to
STEM integration, even when provided one–on–one training or in-class support opportunities. I organized a STEM Day at my home campus in 2018 and 2019 to expose all 1,100 students to STEM opportunities and provide models for teachers to consider its implementation. Few teachers embraced the opportunity to gain experience engaging with integrative STEM and even fewer incorporated STEM into their lesson plans. This reluctance sparked my curiosity and confusion. In conducting this research, I sought to explore teacher self-efficacy in teaching mathematics and science, perceptions of STEM, and professional development interests in implementing STEM education.

I approached this research with a pragmatic and postpositivist perspective with my dialectical pluralistic worldview. Pragmatism calls for multiple perspectives and collecting data in the most practical ways (Creswell & Clark, 2018). Based on pragmatism, Tashakkori and Teddlie (2003) stressed that the research question should be the primary focus rather than a method or philosophical worldview. Creswell and Plano Clark (2018) aligned quantitative studies most closely with postpositivism. Postpositivists do not search for objective knowledge because acquiring knowledge is deemed an interpretive act (Creswell & Creswell, 2018). Knowledge interpretation is constructed from each person’s unique experience and understanding. I sought to collect teacher self-efficacy data and identify elementary teachers’ professional development interests. My postpositivist perspective guided my inquiry into teachers’ unique experiences, social contexts, and perceptions that influence their science and mathematics self-efficacy, STEM instruction, and interest in STEM-related professional development using a survey.
As discussed in Chapter One, I utilized Bandura’s self-efficacy theory, which explains self-efficacy as an assessment of one’s capabilities to attain a desired level of performance in a given endeavor, as the theoretical framework for this study. I chose this framework because it aligned with the purpose of this study, which was to identify the teaching self-efficacy of elementary educators in teaching science and mathematics, examine correlations between the teaching self-efficacy of elementary educators in mathematics and science instruction with their interest in STEM-related professional development and to identify variables that predicted how often elementary teachers reported incorporating integrated STEM in their classrooms.

Bandura’s theory on self-efficacy helped me to shape my research questions. As the theory postulates, teachers with higher self-efficacy are more inclined to prioritize the implementation of new instructional methods (Lee et al., 2013). This application of Bandura’s self-efficacy theory aligns with my first research question, which examines the correlations between teaching self-efficacy in mathematics and science with a teacher’s interest in STEM-related professional development. Bandura’s (2005) self-efficacy theory indicates that high levels of self-efficacy increase a teacher’s willingness to accept innovative ideas and embrace change, which suggests that teachers with high teaching efficacy would be more interested in professional development. Additionally, the professional development of in-service teachers in any content area can increase teacher efficacy to influence students’ learning despite environmental factors or obstacles (Ashton, 1984; Dembo & Gibson, 1985; Desimone et al., 2002). The third research question examines how variables including hours of STEM-related professional development, science and mathematics teaching self-efficacy, and student technology use
predict teachers’ STEM instruction scores or teachers’ frequency of using integrated
STEM. Bandura (1997) asserted that “teachers who believe strongly in their ability to
promote learning create mastery experiences for their students” (p. 241). This suggests
that high teacher self-efficacy results in engaging, enriching learning opportunities such
as integrative STEM instruction.

The self-efficacy theory informed my approach to data collection and data
analysis by guiding how I narrowed the focus of the study to measure the self-efficacy of
teachers and explore the implications of self-efficacy on their teaching and learning. I
administered this cross-sectional survey for this study to elementary teachers in NEISD
using elements of the T-STEM (Friday Institute for Educational Innovation, 2012c) and
MO-STEM (Owens et al., 2018). I specifically selected the teaching efficacy and beliefs
in mathematics and science scales of the T-STEM to measure elementary teachers’ self-
efficacy in teaching mathematics and science. I selected the other scales of the T-STEM
to examine the elementary teachers’ STEM teaching practices, student technology use,
and attitudes about 21st-century learning. The scale from the MO-STEM instrument
collected data regarding professional development interests. Collectively, this data
provides insight into elementary teachers’ attitudes, teaching practices, and interest in
STEM professional development.

I used Bandura’s self-efficacy theory as a framework to explain my results more
deply. I examined the correlation between teaching self-efficacy in mathematics and
science and interest in STEM-related professional development. I also sought to
determine whether science and mathematics teaching self-efficacy predicts teachers’
STEM instruction scores. After analyzing the data, I looked at the specific implications of teaching self-efficacy in mathematics and science.

Research Design and Rationale

This quantitative correlational cross-sectional survey research examines elementary educators’ perceived teaching self-efficacy in mathematics and science, frequency of student technology use, attitudes about 21st-century learning, STEM instruction, and interest in STEM-related professional development. Quantitative data does not naturally measure this type of data. However, converting phenomena, such as reported STEM instruction and student technology use, to factors measured by a survey allows for statistical analysis (Sukamolson, 2007). In this section, I explain the reasoning for each element of the research design, including the quantitative method, survey instrument, and cross-sectional approach.

I preferred a quantitative method given the size of the population of interest, the breadth of data collected, the economy of the design, and the rapid turnaround in the data collection (Creswell & Creswell, 2018). Using a quantitative study rather than a qualitative design calls for a large representative sample allowing for greater generalizability across elementary schools in the district. Quantitative research can also provide insight into establishing causal links that are not viable with other research methods (Field, 2018). Qualitative research is interpretive, seeks to report participants’ voices, and provides a complex understanding of a phenomenon (Creswell & Poth, 2018), which is challenging to do with large numbers of participants because it requires in-depth interviews or observations. I did not utilize a qualitative method because it would not give the amount and scope of data needed to generalize results for the entire
district. A mixed-method approach would have provided both breadth and depth of data, but time constraints impeded its application to this study. A quantitative methodology is most appropriate for measuring associations between variables (Creswell & Creswell, 2018), which aligned with the purpose of my study. Furthermore, quantitative data is often the basis for decisions and accountability, making it best suited to elicit needed change at the designated site (Gaciu, 2020).

A survey can answer descriptive questions regarding trends, perceptions, and attitudes of a sample (Creswell & Creswell, 2018). I used a survey to collect a broad range of data, including teaching self-efficacy in mathematics and science, student technology use, STEM instruction, and attitudes about 21st-century learning (Friday Institute for Educational Innovation, 2012b). In addition, I collected data about the professional development topic interests of participants (Owens et al., 2018). A survey study allows for the designation of predictor variables (e.g., teacher self-efficacy in mathematics and science, number of STEM professional development hours, and student technology use) as it informs the outcome variable, STEM instruction score. A cross-sectional method provides a snapshot of data at one point in time.

An online quantitative survey seemed most appropriate for acquiring a broad range of data. Gunn (2002) noted distinct advantages to online surveys for research, including cost, fast response rate, ease of sending reminders, ease of processing data, variety of options, including question randomization, and error-checking capability. These features were valuable because elementary teachers in the district vary in experience, education, and perspectives. A quantitative study provided general insight into the current state of teachers’ self-efficacy in teaching science and mathematics,
attitudes about 21st-century learning, and the frequency of student technology use and STEM integration in the classroom. In collecting a wide breadth of data, leadership can determine gaps in teacher self-efficacy and plan professional development accordingly (Banilower et al., 2007).

Table 2.1 provides a summary of the quantitative research elements of this study. The population consisted of elementary teachers in NEISD. A total population sampling method was most appropriate to collect as much data as possible. I analyzed data using descriptive statistics, correlations, and predictive multivariate linear regression (Creswell & Creswell, 2018; Simpson, 2015).

Table 2.1

<table>
<thead>
<tr>
<th>Research Design Component</th>
<th>Detail</th>
</tr>
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<tbody>
<tr>
<td>Population</td>
<td>Elementary teachers in NEISD</td>
</tr>
<tr>
<td>Sample Selection</td>
<td>Total population sampling method</td>
</tr>
<tr>
<td>Data Collection: Survey</td>
<td>Friday Institute for Educational Innovation Teacher Efficacy and Attitudes Towards STEM (Friday Institute for Educational Innovation, 2012b), Missouri STEM PD Needs Assessment (Owens et al., 2018)</td>
</tr>
<tr>
<td>Data Analysis Method</td>
<td>Descriptive statistics, correlations, and predictive multivariate linear regression</td>
</tr>
</tbody>
</table>

Site Selection and Participant Sampling

I used a total population sampling method to recruit as many NEISD elementary teachers to participate in this study as possible. As a former elementary teacher in the district, I was most interested in exploring the teaching self-efficacy of elementary
educators in NEISD elementary classrooms and identifying variables that might predict their STEM instruction. The following sections provide specific data on the study site and participants.

Site

The site for this study was Northeast Independent School District (NEISD), which is among the three largest school districts in San Antonio, Texas. NEISD is designated a District of Innovation in Texas, which suggests innovative curricula or practices. Despite this designation, NEISD did not have a standardized STEM program for early childhood education through grade 5 at the time of this study.

At the time of the study, NEISD did not fund STEM programs for grades PK–5. The district provided optional professional development in STEM integration to increase teacher self-efficacy, but there was no required training in integrative STEM. Principals may choose to implement STEM as part of a rotation with music and art, but in most of these cases, paraprofessionals rather than certified teachers lead STEM classes. Some elementary campuses offered 30 to 60 minutes of STEM education per week provided by paraprofessionals. The district did not mandate STEM instruction in elementary school, so most elementary campuses did not offer it. Elementary campuses may choose to host STEM days or STEM nights with the support and funding of community members and/or the Parent Teacher Association (PTA). Elementary teachers at some campuses sponsored extra–curricular STEM clubs that meet outside of instructional hours. Elementary extra–curricular STEM sponsorship is at teachers’ discretion and required a commitment beyond contract hours and funding from external sources.
NEISD employs 4,225 classroom teachers, of which 1,900 are early childhood education through grade 5 across 46 elementary campuses. Of the district teachers, 4% are beginning teachers, 22% have 1–5 years of experience, 21% have 6–10 years of experience, 35% have 11–20 years of experience, and 16% have 21–30 years of experience, and 2% have over 30 years of experience (TEA, 2020). Educators in the district vary in ethnicity, experience, and educational background (TEA, 2020). Table 2.2 includes demographic data from the district based on public records. Each of the 46 elementary campus house kindergarten to fifth–grade classes. Of these, 36 also offer pre–kindergarten.

Participants

A total population sampling method allowed all elementary educators in NEISD the opportunity to participate in the study, thereby collecting a wide breadth of data (Sukamolson, 2007). This methodology is also referred to as a nonprobability sample because respondents were chosen based on their availability and convenience (Creswell & Creswell, 2018). With four predictor variables in my regression equation, the sample size for this study should include a minimum of 40 participants, so at least 10 observations are available for each variable in the regression model (Laerd Statistics, 2015). As a teacher in the district, I had direct access to communicate with district gatekeepers, campus gatekeepers, and all teachers. I invited all 1,900 elementary teachers to participate in the survey. Eighty–nine people responded, translating to a 4.7% response rate.

The participants in this study were elementary educators in NEISD in San Antonio, Texas. The demographic characteristics show an overrepresentation of teachers
with over 10 years of teaching experience, as they account for 75% of the sample, compared to 53% of the elementary teachers in NEISD. The participant sample accurately represented the highest degree held with 65% having a bachelor’s degree and 34% having a master’s degree, compared to 65% of the total population having a bachelor’s degree and 35% having a master’s degree.

Table 2.2

Demographic Characteristics of NEISD Educator Population and Sample

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>Total Population N = 4,225</th>
<th>Participant Sample n = 88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Female</td>
<td>3,246</td>
<td>77%</td>
</tr>
<tr>
<td>Male</td>
<td>979</td>
<td>23%</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>158</td>
<td>4%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1,635</td>
<td>39%</td>
</tr>
<tr>
<td>White</td>
<td>2,331</td>
<td>55%</td>
</tr>
<tr>
<td>American Indian</td>
<td>6</td>
<td>0.1%</td>
</tr>
<tr>
<td>Asian</td>
<td>57</td>
<td>1%</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>8</td>
<td>0.2%</td>
</tr>
<tr>
<td>Two or more races</td>
<td>30</td>
<td>0.7%</td>
</tr>
<tr>
<td>Years of experience</td>
<td>N  = 4,225</td>
<td>n = 88</td>
</tr>
<tr>
<td>Beginning teacher</td>
<td>176</td>
<td>4%</td>
</tr>
<tr>
<td>1–5 years of experience</td>
<td>932</td>
<td>22%</td>
</tr>
<tr>
<td>6–10 years of experience</td>
<td>901</td>
<td>21%</td>
</tr>
<tr>
<td>11–20 years of experience</td>
<td>1,466</td>
<td>35%</td>
</tr>
<tr>
<td>21–30 years of experience</td>
<td>667</td>
<td>16%</td>
</tr>
<tr>
<td>Over 30 years of experience</td>
<td>83</td>
<td>2%</td>
</tr>
<tr>
<td>Highest degree held</td>
<td>N  = 4,225</td>
<td>n = 89</td>
</tr>
<tr>
<td>No degree</td>
<td>23</td>
<td>0.5%</td>
</tr>
<tr>
<td>Bachelors</td>
<td>2,729</td>
<td>65%</td>
</tr>
<tr>
<td>Masters</td>
<td>1,430</td>
<td>34%</td>
</tr>
<tr>
<td>Doctorate</td>
<td>43</td>
<td>1.0%</td>
</tr>
<tr>
<td>Total</td>
<td>N  = 4,225</td>
<td>n = 89</td>
</tr>
</tbody>
</table>

Note. District demographic information (TEA, 2022a) is reported for all teachers in the district, not just elementary teachers.
Most of the participants taught third–, fourth–, or fifth–grade students and taught the five core content areas (reading, language arts, science, social studies, and mathematics). Subject data was not available for the population.

Data Collection Procedures

As the researcher, I collected data on teacher self-efficacy in teaching mathematics and science, student technology use, STEM instruction, attitudes about 21st-century learning, and professional development interests. I chose these data because they indicate the beliefs and attitudes of teachers in STEM areas and teachers report of the frequency of student technology use and integrative STEM instructional practices (Friday Institute for Educational Innovation, 2022). The state of Texas does not require integrative STEM instruction, so the decision to teach it lies solely on the campus administrators or classroom teachers.

I organized the steps of my data collection process into nine steps, as illustrated in Table 2.3. First, I received district site approval via email on March 30, 2022, as provided in Appendix A. Second, I submitted my research to the Office of Research Compliance for review and received a Non-Human Subjects Research (NHSR) determination as provided in Appendix B. Third, I pilot–tested the instrument with nine teachers with a range of credentials like the targeted research population. Pilot testing is important to establish content validity, make necessary revisions, and determine how long the study will take to complete (Creswell & Creswell, 2018).

Fourth, I contacted district gatekeepers for initial meetings to discuss the overview of the research study. Creswell and Creswell (2018) stressed the importance of communicating to gatekeepers relevant information regarding the survey administration. I
ensured gatekeepers that participation in the research would cause minimal disruption, and I was available if any issues arose during the study. Appendix C provides an example of a request for dissemination assistance from district mathematics officials, district instructional technology specialists, and elementary campus administrators to increase credibility and exposure.

In the fifth step, I distributed the instrument to campus gatekeepers who were administrators at perspective campuses. In the sixth step, I invited district elementary teachers to participate in the study via campus principals (see Appendix D). District mathematics specialists and instructional technology personnel shared the email on my behalf as well. The email included a brief introduction about the study and a link to the quantitative survey in Qualtrics (see Appendix E). As part of the survey, I obtained participant consent (see Appendix F). While I did not collect any traceable information about participants, NEISD does monitor all activity on district devices. I did not utilize traceable device data for the purpose of this study. As the seventh step, three days later, I confirmed dissemination with campus administrators. Over the next two weeks, I completed step eight when I sent two reminder emails to all participants (see Appendix G). The survey closed on May 6, 2022, which was step nine.

I commenced with step ten at the end of the data collection window by acknowledging and thanking district and campus gatekeepers. In August 2022, I began cleaning the data and conducting the initial analysis. After backing up the data onto a hard drive, I commenced with analyzing the data using IBM® SPSS® version 28. In October 2022, I interpreted results and reported results based on observations.
Table 2.3

Data Collection and Analysis Timeline

<table>
<thead>
<tr>
<th>Date</th>
<th>Step #</th>
<th>Action or Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2022</td>
<td>1</td>
<td>Obtain research approval from site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Identify and contact campus gatekeepers within the district</td>
</tr>
<tr>
<td>April 2022</td>
<td>2</td>
<td>Obtain IRB determination and research site approval</td>
</tr>
<tr>
<td>April 2022</td>
<td>3</td>
<td>Conduct instrument pilot tests</td>
</tr>
<tr>
<td>April 2022</td>
<td>4</td>
<td>Collaborate with district mathematics and instructional technology teams for assistance with the dissemination</td>
</tr>
<tr>
<td>April 15, 2022</td>
<td>5</td>
<td>Send T-STEM/MO-STEM to administrators of prospective survey participants</td>
</tr>
<tr>
<td>Week of April 18, 2022</td>
<td>6</td>
<td>Survey window opens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disseminate instrument to prospective participants via email link</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Confirm dissemination with campus administrators, offer support as needed</td>
</tr>
<tr>
<td>Week of April 25, 2022</td>
<td>7</td>
<td>Send a first reminder email to survey participant prospects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(due May 6, 2022)</td>
</tr>
<tr>
<td>Week of May 2, 2022</td>
<td>8</td>
<td>Send a second reminder email to survey participant prospects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(due May 6, 2022)</td>
</tr>
<tr>
<td>May 6, 2022</td>
<td>9</td>
<td>Survey window closes</td>
</tr>
<tr>
<td>May 9–12, 2022</td>
<td>10</td>
<td>Send thank-you notes to administrators gatekeepers</td>
</tr>
</tbody>
</table>

Data Collection Survey Instrument

I utilized sections of two different research-based instruments to collect data from teacher participants. Table 2.4 provides an overview of the survey instrument used to
collect data from teacher participants for this study. My survey instrument consists of three sections: demographic questions, teacher self-efficacy and attitudes, and professional development interests. Most of the items came from validated scales. I used sections of the Friday Institute’s (2012c) Teacher Efficacy and Attitudes Towards STEM for Elementary Teachers survey (T-STEM), including personal teaching efficacy and beliefs in mathematics and science, student technology use, STEM instruction, and attitudes about 21st-century learning. I used one scale from the Missouri Teacher Professional Development Survey for K–12 Educators Teaching Science, Technology, Engineering, or Mathematics (MO-STEM) developed by Owens et al. (2018), which was STEM professional development interests.

**Demographic information.** The first section included 30 demographic and open-ended questions about teaching assignments and perceptions of STEM. The three open-ended questions regarding current STEM practices were not analyzed for the purpose of this study. Demographic items collected data about years of experience, the highest level of degree earned, and any specialized degree. Participants also reported what grade levels and what subjects they taught and hours of professional development in different content and pedagogical areas.
<table>
<thead>
<tr>
<th>Question Content</th>
<th># of Items</th>
<th>Measurement Level</th>
<th>Measurement Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q0 Consent</td>
<td>1</td>
<td></td>
<td>Consent</td>
</tr>
<tr>
<td>Q1 Eligibility</td>
<td>1</td>
<td>Binary</td>
<td>Participant teachers PK–5 validation</td>
</tr>
<tr>
<td>Q2 Demographic: Years Teaching</td>
<td>1</td>
<td>Scale</td>
<td>Years of teaching experience</td>
</tr>
<tr>
<td>Q3.1–Q3.7 Professional development history</td>
<td>7</td>
<td>Scale</td>
<td>Hours of specific professional development</td>
</tr>
<tr>
<td>Q4.1–4.2 Demographic: Education</td>
<td>2</td>
<td>Ordinal, nominal</td>
<td>Highest degree and area of specialization</td>
</tr>
<tr>
<td>Q5.1–5.9 Demographic: Teaching assignment: grade</td>
<td>9</td>
<td>Nominal</td>
<td>Grade level or special population taught</td>
</tr>
<tr>
<td>Q6.1–6.8 Demographic: Teaching assignment: subject</td>
<td>8</td>
<td>Nominal</td>
<td>Subject areas taught</td>
</tr>
<tr>
<td>Q7.0–7.2</td>
<td>4</td>
<td>Nominal, Open-ended</td>
<td>Current STEM instruction</td>
</tr>
<tr>
<td>Q8.1–8.11 T-STEM: Science efficacy and beliefs</td>
<td>11</td>
<td>Ordinal, Likert scale–agreement</td>
<td>Efficacy and confidence in teaching science</td>
</tr>
<tr>
<td>Q9.1–9.11 T-STEM: Mathematics efficacy and beliefs</td>
<td>11</td>
<td>Ordinal, Likert scale–agreement</td>
<td>Efficacy and confidence in teaching math</td>
</tr>
<tr>
<td>Q10.1–10.8 T-STEM: Student technology use</td>
<td>8</td>
<td>Ordinal, Likert scale–frequency</td>
<td>Frequency of technology integration in teachers’ classroom</td>
</tr>
<tr>
<td>Q11.1–11.14 T-STEM: Elementary Classroom STEM instruction</td>
<td>14</td>
<td>Ordinal, Likert scale–frequency</td>
<td>Utilization of STEM strategies during instruction</td>
</tr>
<tr>
<td>Q12.1–12.11 T-STEM 21st-century learning attitudes</td>
<td>11</td>
<td>Ordinal, Likert scale–agreement</td>
<td>Ideas about collaboration, critical thinking, and problem-solving</td>
</tr>
<tr>
<td>Q13.1–13.19 MO-STEM Professional development topics</td>
<td>19</td>
<td>Ordinal, Likert scale–interest</td>
<td>Areas of interest for professional development opportunities</td>
</tr>
</tbody>
</table>
**T-STEM.** The second section of the instrument consists of Likert-scale questions from the Teacher Efficacy and Attitudes Towards STEM for Elementary Teachers survey, referred to as T-STEM throughout this study (Friday Institute for Educational Innovation, 2012c). I selected five factors or scales from the T-STEM for this research: teaching science and mathematics efficacy and beliefs, student technology use, elementary STEM instruction, and attitudes about 21st-century learning. The data was self-reported by participants. I requested permission to use the T-STEM by completing the T-STEM Survey for Elementary Teachers: Instrument Request Form. Friday Institute for Educational Innovation granted me access to the survey as well as permission to use it for data collection. Guidance for usage on the cover page of the instrument allows for modification as needed (Friday Institute for Educational Innovation, 2012a). Four subscales (28 questions) of the original T-STEM were not used for this study to decrease the likelihood of participant fatigue. The sections excluded were Science Outcome Expectancy, Mathematics Outcome Expectancy, Teacher Leadership Attitudes, and STEM Career Awareness.

Table 2.5 presents the number of items that comprise each factor measured by the T-STEM. Eleven items per scale each measure science teaching efficacy (Q8.1–8.11) and mathematics teaching efficacy (Q9.1–9.11). Eight items measure student technology use (Q10.1–10.8) and 14 questions STEM instruction (Q11.1–11.14), respectively. The prompt for the elementary STEM instruction section was adjusted in the survey for this research from “During elementary STEM instructional meetings (e.g. class periods, after school activities, days of summer camp, etc.), how often do your students…” to read “During elementary instructional periods, how often do students…” A teacher’s STEM
instruction score reflects the frequency with which their students develop problem-solving skills through investigations, complete activities in a real-world context, recognize patterns in data, in addition to other relevant activities. Eleven items measure the attitudes towards 21st-century learning (Q12.1–12.11). I scored all items in this section on a Likert–scale in which they chose between strongly disagree (coded 1) to strongly agree (coded 5). The mean factor scores used in multiple regression analysis for this section ranged from 1–5. I computed the average factor scores by dividing the summed scores of the items corresponding to each factor for the scale by the number of items for that scale. The survey is provided in Appendix E.

Table 2.5

<table>
<thead>
<tr>
<th>Scale or Factor</th>
<th>Number of items</th>
<th>Potential score range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Teaching Efficacy and Beliefs</td>
<td>11</td>
<td>1–5</td>
</tr>
<tr>
<td>Mathematics Teaching Efficacy and Beliefs</td>
<td>11</td>
<td>1–5</td>
</tr>
<tr>
<td>Student Technology Use</td>
<td>8</td>
<td>1–5</td>
</tr>
<tr>
<td>STEM Instruction</td>
<td>14</td>
<td>1–5</td>
</tr>
<tr>
<td>21st-century Learning Attitudes</td>
<td>11</td>
<td>1–5</td>
</tr>
</tbody>
</table>

I examined the internal consistency of each T-STEM factor for my participant sample using Cronbach’s alpha (see Table 2.6). According to Tavakol and Dennick (2011), acceptable values of Cronbach’s alpha range from 0.7 to 0.95. The Cronbach’s alpha for the Teacher Self-efficacy scales in science and mathematics teaching were above the .8 threshold for a good fit with $\alpha = .87$ and .92, respectively. The Cronbach’s alpha were above the .9 threshold for an excellent fit for three scales: student technology use and elementary STEM instruction (both $\alpha = .94$) and attitudes about 21st-century
learning ($\alpha = .98$). According to Tavakol and Dennick (2011), a high value of alpha, while extremely reliable, may suggest redundancies in the test. Cronbach’s alpha calculated by Friday Institute for Educational Innovation (Friday Institute for Educational Innovation, 2012a) were all in the excellent range.

I also examined the reliability of each T-STEM factor using Cronbach’s alpha (see Table 2.6). The Cronbach’s alpha for the Teacher Self-efficacy scales in science and mathematics teaching were above the .8 threshold for a good fit with $\alpha = .87$ and .92, respectively. The Cronbach’s alpha were above the .9 threshold for an excellent fit for three scales: student technology use and elementary STEM instruction (both $\alpha = .94$) and attitudes about 21st-century learning ($\alpha = .98$).

Table 2.6

<table>
<thead>
<tr>
<th>Subscale or Factor</th>
<th>Number of Items</th>
<th>Cronbach’s $\alpha$</th>
<th>NEISD Reliability Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>among Elementary Teachers ($n = 228$)</td>
<td>($n = 88$)</td>
</tr>
<tr>
<td>Teaching Self-efficacy</td>
<td>11 (science)</td>
<td>.91</td>
<td>.87</td>
</tr>
<tr>
<td></td>
<td>11 (mathematics)</td>
<td>.94</td>
<td>.92</td>
</tr>
<tr>
<td>Student Technology Use</td>
<td>8</td>
<td>.94</td>
<td>.94</td>
</tr>
<tr>
<td>Elementary STEM Instruction</td>
<td>14</td>
<td>.95</td>
<td>.94</td>
</tr>
<tr>
<td>21st-century Learning Attitudes</td>
<td>11</td>
<td>.95</td>
<td>.98</td>
</tr>
</tbody>
</table>

Note. $^1$Cronbach’s alpha statistics were reported by Friday Institute for Educational Innovation (2012). Adapted from “Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey: Development and Psychometric Properties” by Friday Institute for Educational Innovation, 2012. Reprinted with permission.
Creswell and Creswell (2018) stressed the importance of ensuring the validity of an instrument. Three acceptable validity measures for quantitative research are content validity, criterion validity, and construct reliability. While developing the T-STEM, the Friday Institute for Educational Innovation (2012c) established content validity by determining whether the “items fairly sample the universe of items for which the test is designed” (Salkind & Frey, 2020, p. 117) and construct reliability by determining if the items “measure hypothesized constructs or concepts” (Creswell & Creswell, 2018, p. 153). The T-STEM for elementary teachers is based on the work of Riggs and Enoch (1990) to measure the self-efficacy of science teachers. Judges classified the dimension of each item, rated each scale, and rated the total instrument’s content validity. Based on the ratings, Riggs and Enoch (1990) eliminated items that were inconsistently classified by three of the five judges. Enoch and Riggs (1990) determined construct reliability by factor analysis that produced an alpha of 0.92. The presence of both content validity and construct reliability of this instrument enhances the validity of my results (Creswell & Creswell, 2018).

**MO-STEM.** The third section of the instrument was adapted from an instrument developed by the University of Missouri Assessment Resource Center and pertains to professional development (Owens et al., 2018). The Missouri Teacher Professional Development Survey for K–12 Educators Teaching Science, Technology, Engineering, or Mathematics (MO-STEM) has five sections. I requested permission to use the MO-STEM via email and was granted permission to use it by the author. The original instrument included 61 Likert–scale items grouped into four groups. The groups were: timeframe of professional development delivery, preferred format of professional
of professional development programs that teachers found to be important, and professional development topic areas that teachers found to be the most valued (Owens et al., 2018). For this study, I selected only 19 items (of the original 22 items) about professional development topics areas of interest because they were the most relevant questions for my research and to decrease the chance of responder fatigue. I omitted sections related to the timeframe of professional development delivery, preferred format of professional development attendance, and aspects of professional development program that teachers found to be important. Participants in my study were provided the following response options: not interested (coded value = 1), possibly interested (coded value = 2), and definitely interested (coded value = 3). I deleted three items from this section of the MO-STEM because they were not aligned with Texas education standards: Next Generation Science Standards, Common Core state mathematics standards, and new Missouri learning standards. I added items about Science TEKS and Mathematics TEKS. I removed the sections on supporting girls and minorities in STEM and integrating authentic STEM research into the classroom because they did not align with the purpose of this study.

As I used the MO-STEM to collect descriptive information and not to measure constructs, the instrument did not need to be validated. The MO-STEM instrument is based on the work of Chval et al. (2008), which originally measured mathematics and science professional development needs and interests of secondary educators. Owens and his colleagues (2018) explored the preferred format and timeframes of professional development and topics of interest related to STEM subjects of K–12 participants. Based on previous results of the MO-STEM (Assessment Resource Center, 2016), educators
valued accessing ready–to–use materials, learning from other teachers, and learning about new and innovative teaching strategies. This was particularly true among elementary teachers (Assessment Resource Center, 2016, p. 24). Using real-world issues in the classroom were perceived to be the most important topic among MO-STEM participants, and they also reported the highest level of interest in attending professional development about mathematical practices and aligning instruction and curriculum with standards (Assessment Resource Center, 2016).

Data Analysis Procedures

The data analysis steps for this quantitative study come from Creswell and Creswell (2018). The six steps involved in the data analysis process include prepping the data for analysis, exploring the data, analyzing the data, representing the data, interpreting the results, and validating the results. The following paragraphs detail the steps in the analysis of my study.

The first step included cleaning and preparing the data. I downloaded survey responses from Qualtrics into IBM® SPSS® Statistics (v. 28). I manually checked for incomplete surveys. Specifically, I looked for participants that declined to participate and those who did not complete the entire survey. At the conclusion of data collection period, there were 144 total submissions. Of these, none declined to participate, 18 did not meet eligibility criteria, 18 did not complete any of the survey questions, and 19 answered demographic questions but did not complete the scales. Once I removed the ineligible submissions, 89 participants remained in the data set as presented in Table 2.7.

Second, I explored the data. After downloading the data in IBM® SPSS® Statistics (v. 28) and preparing data for analysis, I calculated the frequencies of
demographic information, including years of experience, professional development history, education background, specialty degrees, current grade level assignments, and current subjects taught. I ran descriptive statistics and Pearson’s \( r \) correlations on the T-STEM subscales to observe any general trends in the data. Bergin (2018) notes the importance of running descriptive statistics to “gain greater insight into the features of one’s sample before endeavoring to generalize from that sample to a population” (p. 77). I also calculated the frequencies and percentages of professional development topic interests from the MO-STEM portion of the instrument. I also examined reliability of the T-STEM using Cronbach’s alpha. Internal consistency reliability is “used when you want to know whether the items on a test correlate with one another strongly enough this it makes sense to assume they all measure the same thing” (Salkind & Frey, 2020, p. 110).

### Table 2.7

*Four-Step Data Cleaning*

<table>
<thead>
<tr>
<th>Data Cleaning Criterion Steps</th>
<th>Removed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submissions at survey closing</td>
<td></td>
<td>144</td>
</tr>
<tr>
<td>1) Did not meet eligibility criteria</td>
<td>18</td>
<td>126</td>
</tr>
<tr>
<td>2) Met eligibility but did not complete the survey</td>
<td>18</td>
<td>108</td>
</tr>
<tr>
<td>3) Answered demographic questions but did not complete scales</td>
<td>19</td>
<td>89</td>
</tr>
<tr>
<td>Final cleaned submissions used for analysis</td>
<td></td>
<td>89</td>
</tr>
</tbody>
</table>

Additionally, as part of the data exploration stage, I investigated if my data met the assumptions for each statistical test. I checked the data to ensure they met the six assumptions of multiple linear regression: the linearity of variables, normality of residuals, little or no evidence of multicollinearity, less than 1% overly influential cases,
independent errors, and absence of heteroscedasticity. The alignment of the research questions with statistical reporting is presented in Table 2.8.

### Table 2.8

<table>
<thead>
<tr>
<th>Research question</th>
<th>Statistical test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are NEISD elementary teachers’ self-efficacy in teaching mathematics and science and how does this teaching self-efficacy correlate with their interest in STEM-related professional development topics?</td>
<td>Kendall’s tau $b$</td>
</tr>
<tr>
<td>2. What are NEISD elementary teachers’ attitudes about 21st-century skills and how often do they report implementing integrative STEM?</td>
<td>Descriptive statistics (e.g., mean, standard deviation, median, frequency and percentages)</td>
</tr>
<tr>
<td>3. Do hours of STEM-related professional development, science and mathematics teaching self-efficacy, and technology use predict elementary teachers’ STEM instruction score?</td>
<td>Multiple linear regression</td>
</tr>
</tbody>
</table>

In the third step, I analyzed the data. After I checked for reliability and ensured that assumptions were met for the multiple linear regression, I selected statistical tests that were most appropriate for the research questions. For the first research question, I calculated the Kendall’s tau $b$ correlation using IBM® SPSS® Statistics (v. 28) to determine the relationship between teachers’ self-efficacy in mathematics and science with their interest in STEM-related professional development. The Kendall’s tau $b$ nonparametric correlation was the most appropriate test because I examined the correlations of an ordinal and a scale variable (Field, 2018). I used Pearson’s $r$ correlation coefficients to investigate correlations between T-STEM constructs. According to Field
(2018), ± .1 represents a small effect size, ± .3 represents a medium effect size, and ± .5 represents a large effect size. For research question two, I ran descriptive statistics to explore teachers’ attitudes about 21st-century learning and how often they report implementing integrative STEM practices.

For research question three, I used a multiple linear regression using elementary STEM instruction scores as the outcome variable. This was the most appropriate test because I investigated whether four predictor variables predicted one dependent scale outcome variable (Field, 2018). The purpose of the linear regression was to determine if STEM-related professional development, science teaching self-efficacy, mathematics teaching self-efficacy, or student technology use predicted teachers’ reported frequency of integrated STEM use.

Fourth, I represented the analyzed data. I summarized the statistical results in tables and figures. Fifth, I interpreted the results to confirm or disconfirm the hypotheses for research questions one and three. I also looked for trends or generalizations of the data for research question number two. Sixth, I validated the results by identifying themes among my results, prior literature, and the theoretical framework.

**Ethical Considerations**

In conducting this research, I considered the principles of two ethical theories. According to Evans and Mathur (2018), ethical considerations are important because “abiding by strong codes of ethics will help researchers gain greater trust among all constituencies” (p. 861). The first ethical theory is deontological and focuses on rule-following (Thomas, 1996). I adhered to specific guidelines provided by the NEISD Research and Planning Department to ensure that district protocols and ethical practices
were executed. The teleological perspective is the second ethical framework in which the measure of ethics relates to the consequence of social good or harm (Thomas, 1996).

Consent requests provided to participants included the purpose of the research, the method used, and risks or benefits related to participation. Informed consent provided transparency, and I explained that I would eliminate distinguishing information about study participants, such as name and email address.

My positionality did not interfere with applying ethical practices regarding data analysis. Students benefit from integrative STEM, and in this research, I sought to better understand elementary teachers’ needs and interests that might impact their STEM instruction. For this reason, it was imperative that I objectively analyzed data without consideration of my personal opinions.

The survey used in this study did not collect sensitive data, nor were vulnerable populations involved. Buchanan and Hvizdak (2009) described online studies similar to this one, which “fall into the exempt category of review, indicating that the nature of the data was not overly sensitive nor were vulnerable populations being surveyed” (p. 40). I submitted my study to Baylor’s Office of Research Compliance for review and received a nonhuman subjects determination in April 2022.

To ensure participant willingness, participation in the study was voluntary (Creswell & Clark, 2018). The introduction of the survey sought consent from participants. The study invited educators to participate and did not provide an incentive for participation to ensure that only those who genuinely wanted to contribute to the research did so.
Through the duration of the study, I ensured participants that their information remained confidential. I reported only aggregated data to conceal identities and any distinguishable attributes. Still, Buchanan and Hvizdak (2009) recommend that participants be notified that “as an online participant in this research, there is always the risk of intrusion by outside agents, i.e., hacking, and therefore the possibility of being identified” (p. 45). All precautions taken were intended to secure the privacy of participants, but they were notified about the inherent risks of any online survey in the consent form.

**Limitations**

Identifying limitations is an essential step in research as it allows the reader to understand potential constraints (Creswell & Creswell, 2018). This study is subject to four limitations. In this section, I state each perceived limitation, and what, if anything, I did to minimize the limitation.

First, there is no clear and distinct definition of STEM education despite being a topic of academic research for over three decades (Bybee, 2013). There is even less certainty about integrated STEM education and what it looks like in an elementary classroom. In this study, I did not provide participants of this study with a definition of STEM education, but a definition was not necessary for participants to respond to the survey items.

The second limitation to this study is the sample size and how representative the participants in the sample are of the overall population. “A larger sample will provide more accuracy in the inferences made” (Creswell & Creswell, 2018, p. 151), but recruiting participants proved to be challenging. As noted in Chapter Two, participants
who completed the study only reflected 4.7% of the total population of pre–kindergarten through fifth grade teachers in NEISD. Therefore, I cannot be certain that the responses of participating teachers represented perceptions and interests of all NEISD elementary teachers. It is possible that teachers who were more invested in the topic were more likely to complete the survey. Demographically, the sample had similarities and differences to the population. The sample did closely reflect the education of the entire population as 65% of the sample and the population have bachelor’s degrees. Also, a similar ratio existed between the population (34%) and the participants (35%) who reported having 11–20 years of experience. The sample did not reflect the ratio of novice teachers with 10 years of experience or less; 47% of the population had 10 years or less of teaching experience compared to 26% of the sample participants who reported having 10 years or less of teaching experience. The sample overrepresented participants with 21 years or more of teaching experience. Of the total population, 18% of teachers have 21 or more years of experience, where 41% of the sample reported having 21 years of more of teaching experience. Therefore, it is possible that a larger sample would more accurately represent the population, which could have resulted in different answers.

Third, self-reporting also created a potential limitation in response bias if participants presented themselves in socially desirable ways rather than what was actually the case. According to Grimm (2010), social desirability is the “tendency of research subjects to choose responses they believe are more socially desirable or acceptable rather than choosing responses that are reflective of their true thoughts or feelings” (p. 1). Results may not accurately reflect the perceptions and self-efficacy of participants if they
were not honest in their responses. However, if participants trusted that the online survey was confidential, the likelihood of response bias is decreased (Evans & Mathur, 2018).

Fourth, there are limitations due to unmeasured variables or circumstances that have the potential to affect the study. High stress and excessive demands placed on teachers may interfere with participant recruitment limiting participation or completion of the study. This potentially limits the quality and quantity of data collected. Time constraints, lack of resources, varying campus initiatives, and pressures regarding standardized tests are potential variables that may impact teachers’ integration of STEM instruction, but I did not measure those in this study. The comprehensiveness of the data may be negatively impacted by variables that I did not measure, but the variables I did measure mostly aligned with the results of previous studies (Brophy et al., 2008; Margot & Kettler, 2019).

Conclusion

The purpose of this study was to identify the teaching self-efficacy of elementary educators in teaching science and mathematics, examine correlations between teaching self-efficacy of elementary educators in mathematics and science instruction with their interest in STEM-related professional development and to identify variables that predicted how often elementary teachers reported incorporating integrated STEM in their classrooms. The correlational cross-sectional survey research provided data for insight into the science and mathematics teaching self-efficacy, attitudes about 21st-century learning, student technology use, and STEM integration of NEISD elementary teachers. This chapter presented the participants, site, instruments, data collection, and data analysis process. Ethical considerations and limitations concluded the chapter. The results
of this study have implications for professional development designers, teacher
preparation programs, and elementary administrators. The following chapter includes the
study results, a discussion, implications, and recommendations.
CHAPTER THREE
Results and Implications

Introduction

Innovative teaching practices and exposure to integrative STEM impact students’ attitudes and interests in STEM content and, ultimately, their pursuit of STEM degrees and careers (Toma & Greca, 2018). The purpose of this study was to identify the teaching self-efficacy of elementary educators in teaching science and mathematics, examine correlations between teaching self-efficacy of elementary educators in mathematics and science instruction with their interest in STEM-related professional development and to identify variables that predicted how often elementary teachers reported incorporating integrated STEM in their classrooms. Within this correlational cross-sectional survey research, I collected data to answer the following research questions:

1. What are NEISD elementary teachers’ self-efficacy in teaching mathematics and science and how does this teaching self-efficacy correlate with their interest in STEM-related professional development topics?

   \( H_0: \) No statistically significant correlation exists between NEISD elementary teachers’ teaching self-efficacy in mathematics and teaching self-efficacy in science with their interest in STEM-related professional development.

   \( H_1: \) A statistically significant correlation exists between NEISD elementary teachers’ teaching self-efficacy in mathematics and teaching self-efficacy in science with their interest in STEM-related professional development.

2. What are NEISD elementary teachers’ attitudes about 21st-century skills and how often do they report implementing integrative STEM?
3. Do hours of STEM-related professional development, science and mathematics teaching self-efficacy, and technology use predict elementary teachers’ STEM instruction score?

\[ H_0: \] Elementary teachers’ hours of STEM-related professional development in the past year, science teaching efficacy, mathematics teaching efficacy, and student technology use do not statistically significantly predict their STEM instruction score.

\[ H_1: \] Elementary teachers’ hours of STEM-related professional development in the past year, science teaching efficacy, mathematics teaching efficacy, and student technology use statistically significantly predict their STEM instruction score.

This chapter presents results on the relationship between multiple variables, including hours of STEM-related professional development, science and mathematics teaching self-efficacy, student technology use, attitudes about 21st-century skills, and STEM instruction. This chapter reveals that self-efficacy in teaching mathematics and science has very little relationship with interest in STEM-related professional development among elementary teachers, and student technology use is the most prominent individual predictor of a teacher’s STEM instruction score. First, I summarize the data preparation, which includes data cleaning, creating new factors, and checking for the reliability of scales. Second, for demographic characteristics (e.g., years of experience, grade level taught, STEM-related degrees, hours of STEM professional development), I report frequencies and percentages. Third, I report descriptive statistics for each scale (e.g., teacher self-efficacy in mathematics and science, student technology use, attitudes about 21st-century learning, and elementary STEM instruction), including the mean and standard deviation, as well as the frequencies and percentages for MO-STEM items regarding interest in STEM professional development topics (e.g., interest in using real-world issues in the classroom or problem-based learning). Fourth, I discuss the
quantitative results of the analyses for each research question. Fifth, I include a
discussion of the main points that relate to the literature review and echo the theoretical
framework of Bandura’s (1978) self-efficacy theory. Sixth, I present the implications of
the results as they advance research in integrative STEM practices in elementary
classrooms and make recommendations for future research regarding professional
development in integrative STEM practices for elementary teachers. Lastly, I end with a
summary and conclusion.

This section describes the steps to clean and prepare the data for analysis.
Initially, I collected responses from 144 participants between April 18th and May 6th of
2022. All participants provided consent. From the 144 participants, I removed 18
respondents who were ineligible because they indicated they were not “a Pre–K through
grade 5 teacher in NEISD.” Of the 126 remaining eligible respondents, I removed 18 who
did not answer any items after the eligibility question (Q1). Finally, I removed 19
participants who answered demographic questions but did not complete any of the scales
regarding self-efficacy, teaching practices, or interest in STEM professional development
topics. The total number of cleaned submissions I used for analysis was 89. Table 2.7
includes the steps for data cleaning. I downloaded the survey data from Qualtrics, and
IBM® SPSS® Statistics (v. 28) automatically coded all items (see Table 3.1).
<table>
<thead>
<tr>
<th>Question Content</th>
<th># of Items</th>
<th>Measurement Level</th>
<th>Coding</th>
<th>Measurement Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q0 Consent</td>
<td>1</td>
<td>Binary</td>
<td>1 = Yes; 2 = No</td>
<td>Consent</td>
</tr>
<tr>
<td>Q1 Eligibility</td>
<td>1</td>
<td>Binary</td>
<td></td>
<td>Participant teachers</td>
</tr>
<tr>
<td>Q2 Demographic:</td>
<td>1</td>
<td>Scale</td>
<td>N.A.</td>
<td>Years of teaching</td>
</tr>
<tr>
<td>Years Teaching</td>
<td></td>
<td></td>
<td></td>
<td>experience</td>
</tr>
<tr>
<td>Q3.1–Q3.7</td>
<td>7</td>
<td>Scale</td>
<td>N.A.</td>
<td>Hours of specific</td>
</tr>
<tr>
<td>Professional</td>
<td></td>
<td></td>
<td></td>
<td>professional</td>
</tr>
<tr>
<td>development history</td>
<td></td>
<td></td>
<td></td>
<td>development</td>
</tr>
<tr>
<td>Q4.1</td>
<td>1</td>
<td>Ordinal</td>
<td>1 = Some college</td>
<td>Highest degree</td>
</tr>
<tr>
<td>Demographic:</td>
<td></td>
<td></td>
<td>2 = Bachelor’s degree</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td>3 = Master’s degree</td>
<td></td>
</tr>
<tr>
<td>Q4.2</td>
<td>1</td>
<td>Nominal</td>
<td>4 = Science</td>
<td>Area of specialization</td>
</tr>
<tr>
<td>Demographic:</td>
<td></td>
<td></td>
<td>5 = Mathematics</td>
<td></td>
</tr>
<tr>
<td>Specialty degree</td>
<td></td>
<td></td>
<td>6 = Computer Science or Technology Integration</td>
<td></td>
</tr>
<tr>
<td>Q5.1–5.9</td>
<td>9</td>
<td>Nominal</td>
<td></td>
<td>Grade level or special</td>
</tr>
<tr>
<td>Teaching assignment</td>
<td></td>
<td></td>
<td></td>
<td>population</td>
</tr>
<tr>
<td>Q6.1–6.8</td>
<td>8</td>
<td>Nominal</td>
<td></td>
<td>Subject areas taught</td>
</tr>
<tr>
<td>Teaching assignment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q7.0–7.2</td>
<td>3</td>
<td>Nominal, Open–ended</td>
<td>4 = Yes</td>
<td>Current STEM instruction</td>
</tr>
<tr>
<td>STEM instruction</td>
<td></td>
<td></td>
<td>5 = No</td>
<td></td>
</tr>
<tr>
<td>Q8.1–8.11</td>
<td>11</td>
<td>Ordinal, Likert scale–agreement</td>
<td>1 = Strongly disagree</td>
<td>Efficacy and confidence in teaching science</td>
</tr>
<tr>
<td>T-STEM: Science teaching efficacy and beliefs</td>
<td></td>
<td></td>
<td>2 = Disagree</td>
<td></td>
</tr>
<tr>
<td>Q9.1–9.11</td>
<td>11</td>
<td>Ordinal, Likert scale–agreement</td>
<td>3 = Neither agree nor disagree</td>
<td>Efficacy and confidence in teaching mathematics</td>
</tr>
<tr>
<td>T-STEM: Mathematics teaching efficacy and beliefs</td>
<td></td>
<td></td>
<td>4 = Agree</td>
<td></td>
</tr>
<tr>
<td>Q10.1–10.8</td>
<td>8</td>
<td>Ordinal, Likert scale–agreement</td>
<td>5 = Strongly agree</td>
<td>Frequency of technology integration in classroom</td>
</tr>
<tr>
<td>T-STEM: Student technology use</td>
<td></td>
<td></td>
<td>1 = Never</td>
<td></td>
</tr>
<tr>
<td>Q11.1–11.14</td>
<td>14</td>
<td>Ordinal, Likert scale–frequency</td>
<td></td>
<td>Utilization of STEM strategies during instruction</td>
</tr>
<tr>
<td>T-STEM: Classroom STEM instruction</td>
<td></td>
<td></td>
<td>2 = Occasionally</td>
<td></td>
</tr>
<tr>
<td>Q12.1–12.11</td>
<td>11</td>
<td>Ordinal, Likert scale–agreement</td>
<td>3 = About half the time</td>
<td>Ideas about collaboration, critical thinking, and problem-solving</td>
</tr>
<tr>
<td>T-STEM 21st-century learning attitudes</td>
<td></td>
<td></td>
<td>4 = Usually</td>
<td></td>
</tr>
<tr>
<td>Q13.1–13.19 MO-STEM Professional development topics</td>
<td>19</td>
<td>Ordinal, Likert scale–interest</td>
<td>5 = Every time</td>
<td>Areas of interest for professional development opportunities</td>
</tr>
</tbody>
</table>
I computed factor–level variables by summing the score of the items that corresponded with each factor and averaging the scores of the items that corresponded with each scale for the following scales: science teaching efficacy and beliefs, mathematics teaching efficacy and beliefs, student technology use, STEM instruction, and attitudes about 21st-century learning. Two items in the T-STEM teaching self-efficacy scales (Q8.5 and Q9.5) were reverse–coded because they were negatively worded, and “must be assigned values in the reverse order of all the other questions (“5” for strongly disagree, “4 for disagree,” etc.), since agreement to those questions represents at attitude opposite of the attitude for agreement with the other questions” (Friday Institute for Educational Innovation, 2012b). I present the reverse–coded values in Table 3.2.

For each factor, I checked reliability using Cronbach’s α (see Table 2.7). Acceptable values of Cronbach’s alpha range from 0.7 to 0.95 (Tavakol & Dennick, 2011). The Cronbach’s alpha based on my sample participants were above the.8 threshold for all T-STEM scales, suggested a good fit (ranging from $\alpha = .87$ to .98. According to Tavakol and Dennick (2011), a high value of alpha, while extremely reliable, may suggest redundancies in the test.

Table 3.2

Reverse–Coding Values for the Teacher Self-efficacy Items

<table>
<thead>
<tr>
<th>Original Response</th>
<th>Original Value Code</th>
<th>Value after Reverse Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Disagree</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Neither Agree or Disagree</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Agree</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>
It was necessary to recode responses of questions asking about participants’ professional development hours (e.g., 3.3, 3.4, and 3.5) before I calculated a total number of STEM hours of professional development by combining number of hours of mathematics, science, and technology professional development. Question 3 asked participants how many hours of professional development in each listed area they had participated in over the last 12 months, with 7 areas included. Participants responded using a slider with a minimum of 0 hours and a maximum of 10 hours. Some participants did not respond to each question reporting their mathematics, science, and technology professional development. In this instance, I handled the blank response in one of two ways. The first way, if participants had entered 1 or more hours for each of the other sliders, blank entries were coded as 0 hours. My logic for this approach was that if the participant’s other recorded entries were all 1 hour or more, then an unmoved slider likely indicated 0 hours. The second approach, if a participant’s recorded entries included one or more 0, I made no changes to their blank cells because I assumed if the participant knowingly represented 0 hours on a slider for one area, then I inferred that they chose not to enter data for entries left blank.

Quantitative Data Analysis and Results

I reported demographic information of participants and descriptive statistics for the research scales to provide an overview of the data collected. I utilized IBM® SPSS® Statistics (v. 28) to analyze and report statistics. Next, I report the results from the statistical tests for each research question.
**Demographics**

I collected the following demographic information from the participants: years of experience teaching, the highest level of education, specialty degree information, professional development history, subjects taught, and grade levels taught. Table 3.3 provides information on years of teaching experience, highest degree held, and specialty degrees.

**Table 3.3**

**Demographic Characteristics of Sample**

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>Participant Sample (N = 89)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td><strong>Years of experience</strong></td>
<td></td>
</tr>
<tr>
<td>Beginning teacher</td>
<td>0</td>
</tr>
<tr>
<td>1–5 years of experience</td>
<td>11</td>
</tr>
<tr>
<td>6–10 years of experience</td>
<td>11</td>
</tr>
<tr>
<td>11–20 years of experience</td>
<td>30</td>
</tr>
<tr>
<td>21–30 years of experience</td>
<td>30</td>
</tr>
<tr>
<td>Over 30 years of experience</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>n</td>
</tr>
<tr>
<td></td>
<td>88</td>
</tr>
<tr>
<td><strong>Highest degree held</strong></td>
<td></td>
</tr>
<tr>
<td>No degree</td>
<td>0</td>
</tr>
<tr>
<td>Bachelors</td>
<td>58</td>
</tr>
<tr>
<td>Masters</td>
<td>31</td>
</tr>
<tr>
<td>Doctorate</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>89</td>
</tr>
<tr>
<td><strong>Specialty degree</strong></td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>2</td>
</tr>
<tr>
<td>Math</td>
<td>7</td>
</tr>
<tr>
<td>Computer Science/Technology</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>48</td>
</tr>
<tr>
<td>None</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>n</td>
</tr>
<tr>
<td></td>
<td>88</td>
</tr>
</tbody>
</table>
The average teaching experience among participants was 17 \((SD = 8.4)\) years. Most of the participants (75%) had 11 or more years of experience. All participants held at least a bachelor’s degree. Approximately 65\% \((n = 58)\) of participants earned a bachelor’s degree and 35\% \((n = 31)\) reported obtaining a master’s degree. Only 11\% \((n = 10)\) had STEM-related degrees (e.g., science, mathematics, computer science/technology), while 34\% \((n = 30)\) of participants did not have a specialty degree at all.

Participants reported grade levels and subjects taught as recorded in Table 3.4. Many respondents teach more than one grade level and a large majority of them teach more than one subject area. There were more respondents who reported teaching upper grades (3–5) than reported teaching lower grades (PreK–2). The fewest respondents teach pre-kindergarten and gifted and talented. Not all campuses in NEISD have pre-kindergarten programs. Services for gifted and talented students are provided at all elementary schools, but not all campuses have a designated gifted and talented teacher.

Over 80\% of participants reported teaching mathematics, reading, and language arts with slightly fewer reporting they teach science and social studies (see Table 3.4). This is consistent with the structure of elementary classrooms in which one teacher spends most of the day teaching all content areas to one group of students. While not a core content area, 64\% of participants report teaching social-emotional learning skills to their students. Music and physical education were taught by 6\% and 3\% of the respondents, respectively.
Table 3.4

*Grades and Subjects Taught of Participants*

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>Participant Sample (N = 89)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade(s) taught</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Pre–kindergarten</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>16</td>
<td>18%</td>
</tr>
<tr>
<td>First grade</td>
<td>17</td>
<td>19%</td>
</tr>
<tr>
<td>Second grade</td>
<td>21</td>
<td>24%</td>
</tr>
<tr>
<td>Third grade</td>
<td>29</td>
<td>33%</td>
</tr>
<tr>
<td>Fourth grade</td>
<td>21</td>
<td>24%</td>
</tr>
<tr>
<td>Fifth grade</td>
<td>26</td>
<td>29%</td>
</tr>
<tr>
<td>Special education</td>
<td>7</td>
<td>8%</td>
</tr>
<tr>
<td>Gifted and talented</td>
<td>3</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>n</td>
<td>142*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject taught</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading</td>
<td>75</td>
<td>84%</td>
</tr>
<tr>
<td>Language arts</td>
<td>74</td>
<td>83%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>76</td>
<td>85%</td>
</tr>
<tr>
<td>Science</td>
<td>68</td>
<td>76%</td>
</tr>
<tr>
<td>Social studies</td>
<td>70</td>
<td>79%</td>
</tr>
<tr>
<td>Music</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>Physical education</td>
<td>3</td>
<td>3%</td>
</tr>
<tr>
<td>Social emotional learning</td>
<td>57</td>
<td>64%</td>
</tr>
<tr>
<td>Total</td>
<td>n</td>
<td>428*</td>
</tr>
</tbody>
</table>

*Note.* Some participants reported teaching more than one grade level or subject, so n exceeds the total sample.

*Descriptive Statistics*

I report the mean, median, and standard deviation for each subscale factor in the study. Table 3.5 includes subscale factor scores for the T-STEM items. Teachers expressed the highest level of agreement to items indicating the importance that students have learning opportunities to practice 21st-century skills (M = 4.6, SD = 0.71). Self-efficacy in teaching mathematics (M = 4.16, SD = 0.61), on average, was higher than
science teaching self-efficacy ($M = 3.84, SD = 0.69$). This indicates that most teachers agreed (coded = 4) or strongly agreed (coded = 5) with items affirming their mathematics teaching confidence. Most science teaching self-efficacy responses ranged from neither agree nor disagree (coded = 3) to agree. Teachers reported, on average, that students engaged in STEM skills slightly more than half the time (coded = 3) during elementary instructional periods ($M = 3.29, SD = 0.78$). According to respondents, on average, student technology use ranged from occasionally (coded = 2) to about half the time, but this factor had the largest standard deviation ($M = 2.65, SD = 0.99$) among the five subscales, indicating teachers responded with more variability.

It is worth noting that the three highest rated subscale factors from the T-STEM instrument reported teachers’ attitudes or perceived teaching self-efficacy. These three subscales were science teaching efficacy and beliefs, mathematics teaching efficacy and beliefs, and attitudes about 21st-century learning. The two lowest-rated subscale factors inquired into what respondents and their students do in the classroom. Scales that measured reported activity were the frequency of STEM instruction and student technology use.

Table 3.5

<table>
<thead>
<tr>
<th>Subscale Factors</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>Mdn</th>
</tr>
</thead>
<tbody>
<tr>
<td>21st-century Learning Attitudes</td>
<td>71</td>
<td>4.6</td>
<td>0.71</td>
<td>4.82</td>
</tr>
<tr>
<td>Mathematics Teaching Self-efficacy</td>
<td>83</td>
<td>4.16</td>
<td>0.61</td>
<td>4.09</td>
</tr>
<tr>
<td>Science Teaching Self-efficacy</td>
<td>88</td>
<td>3.84</td>
<td>0.69</td>
<td>3.90</td>
</tr>
<tr>
<td>Elementary STEM Instruction</td>
<td>75</td>
<td>3.29</td>
<td>0.78</td>
<td>3.43</td>
</tr>
<tr>
<td>Student Technology Use</td>
<td>81</td>
<td>2.65</td>
<td>0.99</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Note. The potential range of average scores for each factor is 1–5.
I used Pearson’s $r$ correlation coefficients to investigate correlations between T-STEM constructs. According to Field (2018), ± .1 represents a small effect size, ± .3 represents a medium effect size, and ± .5 represents a large effect size. Correlation results for T-STEM factor scales are presented in Table 3.6.

**Table 3.6**

*Pearson r Correlation Coefficients for Relationships between Factor Scales*

<table>
<thead>
<tr>
<th>Factor Subscales</th>
<th>Science Teaching Self-efficacy</th>
<th>Mathematics Teaching Self-efficacy</th>
<th>Student Technology Use</th>
<th>Elementary STEM Instruction</th>
<th>21st-century Learning Attitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Science Self-efficacy</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2. Mathematics Self-efficacy</td>
<td>.52** [.34, .66]</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3. Student Technology Use</td>
<td>.24* [.02, .43]</td>
<td>.18 [-.04, .39]</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>4. Elementary STEM Instruction</td>
<td>.24* [.01, .44]</td>
<td>.27* [.05, .47]</td>
<td>.55** [.37, .69]</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5. 21st-century Learning Attitudes</td>
<td>.06 [-.17, .29]</td>
<td>.18 [-.06, .4]</td>
<td>-.06 [-.29, .18]</td>
<td>-.04 [-.27, .19]</td>
<td>—</td>
</tr>
</tbody>
</table>

*Notes.* *Correlation is significant at .05 level. **Correlation is significant at .01 level.*

The strongest correlation between these factor scales was between elementary STEM instruction and student technology use ($r = .55$). This large correlation was positive and statistically significant. A positive, strong, statistically significant correlation also existed between science teaching self-efficacy and mathematics teaching self-efficacy ($r = .52$). Small to medium-sized, statistically significant correlations were present between both
science teaching self-efficacy and student technology use \((r = .24)\), and science teaching self-efficacy and elementary STEM instruction \((r = .24)\). A small to medium, statistically significant positive correlation \((r = .27)\) existed between mathematics teaching self-efficacy and elementary STEM instruction. However, results from this study show a small, statistically insignificant, positive relationship between mathematics teaching self-efficacy and student technology use \((r = .18)\). The scale measuring 21st-century learning attitudes was not related to any other scales (given \(r = -.06\) to .06) besides mathematics teaching self-efficacy \((r = .18)\).

The third section of my survey consisted of a portion of the MO-STEM assessment. The scale included from MO-STEM measured participants’ interest in STEM-related professional development topics as presented in Table 3.7. Over half of the respondents reported being *definitely interested* in six of the topics. These six topics were: using real-world issues in the classroom (64%), instructional strategies for meeting the needs of diverse learners (58%), integrating literacy practices with STEM learning (55%), problem-based learning (54%), and integrating science, technology, engineering, and mathematics (52%). Of the respondents, 75% or more are possibly to definitely interested in all of the topics listed in Table 3.7, with the exception of two topics (preparing students for achievement tests and analysis of “big data”). The six topics with the least interest were: preparing students for achievement tests (30%), analysis of “big data” (27%), science Texas Essential Knowledge and Skills (TEKS; 24%), mathematics TEKS (23%), supporting classroom discourse (23%), and engineering design practice (20%).
Table 3.7

MO-STEM Interest in Professional Development Topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Not interested</th>
<th>Possibly interested</th>
<th>Definitely interested</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on your current teaching assignment, how interested would you be in participating in professional development about these topics?</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Using real-world issues in the classroom</td>
<td>3</td>
<td>5%</td>
<td>21</td>
<td>32%</td>
</tr>
<tr>
<td>Instructional strategies for meeting the needs of diverse learners</td>
<td>4</td>
<td>6%</td>
<td>24</td>
<td>36%</td>
</tr>
<tr>
<td>Integrating literacy practices with STEM learning</td>
<td>8</td>
<td>12%</td>
<td>22</td>
<td>33%</td>
</tr>
<tr>
<td>Use of education technology to support learning</td>
<td>5</td>
<td>7%</td>
<td>26</td>
<td>39%</td>
</tr>
<tr>
<td>Problem-based learning</td>
<td>5</td>
<td>8%</td>
<td>26</td>
<td>39%</td>
</tr>
<tr>
<td>Integrating science, technology, engineering, and mathematics</td>
<td>5</td>
<td>8%</td>
<td>27</td>
<td>41%</td>
</tr>
<tr>
<td>Interdisciplinary STEM learning</td>
<td>9</td>
<td>14%</td>
<td>25</td>
<td>38%</td>
</tr>
<tr>
<td>Mathematical practices</td>
<td>7</td>
<td>11%</td>
<td>27</td>
<td>42%</td>
</tr>
<tr>
<td>Strategies for student use of mobile technologies (iPads, Chromebooks, smart phones)</td>
<td>6</td>
<td>9%</td>
<td>29</td>
<td>44%</td>
</tr>
<tr>
<td>Inquiry–based laboratory activities</td>
<td>10</td>
<td>15%</td>
<td>25</td>
<td>38%</td>
</tr>
<tr>
<td>Mathematics TEKS</td>
<td>15</td>
<td>23%</td>
<td>22</td>
<td>33%</td>
</tr>
<tr>
<td>Aligning instruction and curriculum standards</td>
<td>10</td>
<td>15%</td>
<td>32</td>
<td>48%</td>
</tr>
<tr>
<td>Formative assessment for STEM learning</td>
<td>10</td>
<td>15%</td>
<td>33</td>
<td>50%</td>
</tr>
<tr>
<td>Supporting classroom discourse</td>
<td>15</td>
<td>23%</td>
<td>29</td>
<td>44%</td>
</tr>
<tr>
<td>Science TEKS</td>
<td>16</td>
<td>24%</td>
<td>28</td>
<td>42%</td>
</tr>
<tr>
<td>Scientific practices (modeling and argumentation)</td>
<td>10</td>
<td>15%</td>
<td>36</td>
<td>55%</td>
</tr>
<tr>
<td>Preparing students for achievement tests</td>
<td>20</td>
<td>30%</td>
<td>26</td>
<td>39%</td>
</tr>
<tr>
<td>Analysis of “big data”</td>
<td>18</td>
<td>27%</td>
<td>30</td>
<td>45%</td>
</tr>
<tr>
<td>Engineering design practices</td>
<td>13</td>
<td>20%</td>
<td>38</td>
<td>58%</td>
</tr>
</tbody>
</table>
Research Question One Results

RQ1: What are NEISD elementary teachers’ self-efficacy in teaching mathematics and science and how does this teaching self-efficacy correlate with their interest in STEM-related professional development topics?

To answer research question one, I ran Kendall’s tau $b$ correlation between teachers’ interest in STEM-related professional development topics with their self-efficacy in teaching mathematics and with their self-efficacy in teaching science. To interpret Kendall’s tau $b$ associations, I classified an association of less than ±.10 as very weak, ±.10 to 0.19 as weak, ±.20 to .29 as moderate, and ± 30 or above as strong according to Botsch’s (2014) guidelines.

I found only one statistically significant correlation, which I illustrate in Table 3.8. The only statistically significant correlation among science teaching self-efficacy was a negative correlation with learning about mathematics TEKS, $t_b = - .24, p = .02$. Therefore, I reject the null hypothesis and can accept the alternative hypothesis only for the negative correlation between science teaching self-efficacy and learning about mathematics TEKS. This suggests that as science teaching self-efficacy increases, interest in learning about mathematics TEKS decreases. This was the only statistically significant correlation between science teaching self-efficacy and any STEM-related professional development interests. I failed to reject the null hypothesis for every other tested correlation.

Other correlations between STEM professional development topics and science teaching self-efficacy were weak to moderately meaningful but not statistically significant (see Table 3.8). These include a weak positive correlation between science teaching self-efficacy with interdisciplinary STEM learning ($t_b = .13, p = .21$), a weak negative association with mathematics practices ($t_b = -.16, p = .12$), and a negative
association with science TEKS \( t_b = -.17, p = .09 \). Among these participants, these negative associations suggest that as the self-efficacy in teaching science increases, interest in professional development about mathematics practices or science TEKS decreases. Alternatively stated, this association indicates as self-efficacy in teaching science decreases, interest in professional learning about mathematics practices or science TEKS increases. Very weak and nonsignificant relationships existed between science teaching self-efficacy and all the remaining professional learning topics listed in Table 3.8.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Science Teaching Self-efficacy</th>
<th>Mathematics Teaching Self-efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interdisciplinary STEM learning</td>
<td>.13</td>
<td>.01</td>
</tr>
<tr>
<td>Engineering design practices</td>
<td>.07</td>
<td>-.11</td>
</tr>
<tr>
<td>Inquiry–based laboratory activities</td>
<td>.02</td>
<td>.11</td>
</tr>
<tr>
<td>Scientific practices (modeling and argumentation)</td>
<td>.01</td>
<td>-.09</td>
</tr>
<tr>
<td>Strategies for student use of mobile technologies (iPads, Chromebooks, smart phones)</td>
<td>.01</td>
<td>.10</td>
</tr>
<tr>
<td>Formative assessment for STEM learning</td>
<td>.00</td>
<td>.03</td>
</tr>
<tr>
<td>Problem-based learning</td>
<td>.00</td>
<td>.07</td>
</tr>
<tr>
<td>Using real-world issues in the classroom</td>
<td>-.01</td>
<td>.10</td>
</tr>
<tr>
<td>Preparing students for achievement tests</td>
<td>-.02</td>
<td>.17</td>
</tr>
<tr>
<td>Integrating literacy practices with STEM learning</td>
<td>-.03</td>
<td>.03</td>
</tr>
<tr>
<td>Aligning instruction and curriculum standards</td>
<td>-.03</td>
<td>-.10</td>
</tr>
<tr>
<td>Topic</td>
<td>Science Teaching Self-efficacy</td>
<td>Mathematics Teaching Self-efficacy</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Use of education technology to support learning</td>
<td>-.04</td>
<td>-.02</td>
</tr>
<tr>
<td>Instructional strategies for meeting the needs of diverse learners</td>
<td>-.04</td>
<td>.05</td>
</tr>
<tr>
<td>Integrating science, technology, engineering, and mathematics</td>
<td>-.05</td>
<td>-.00</td>
</tr>
<tr>
<td>Supporting classroom discourse</td>
<td>-.07</td>
<td>.08</td>
</tr>
<tr>
<td>Analysis of “big data”</td>
<td>-.09</td>
<td>.06</td>
</tr>
<tr>
<td>Mathematical practices</td>
<td>-.16</td>
<td>.15</td>
</tr>
<tr>
<td>Science TEKS</td>
<td>-.17</td>
<td>-.18</td>
</tr>
<tr>
<td>Mathematics TEKS</td>
<td>-.24*</td>
<td>.04</td>
</tr>
</tbody>
</table>

Note. *Correlation is significant at .05 level.

There were no statistically significant correlations between mathematics teaching self-efficacy and reported interested in any of the STEM professional development topics. A weak, negative correlation existed between professional development related to science TEKS and mathematics teaching self-efficacy ($t_b = -.18, p = .07$). A weak, positive correlation existed between mathematics teaching self-efficacy and both interest in professional development about preparing students for achievement tests ($t_b = .17, p = .09$) and mathematical practices ($t_b = .15, p = .15$). This data suggests that, among this sample, as self-efficacy in teaching mathematics increases, interest in professional development on preparing students for achievement tests and in mathematical practices also increases. As such, I infer those teachers with higher self-efficacy in teaching mathematics are more interested in becoming even better teachers by learning best practices in teaching mathematics and preparing students for achievement tests.
Interestingly, there is essentially no correlation ($t_b = .04$) between mathematics teaching self-efficacy and interest in professional development about mathematics TEKS.

To summarize the notable results from research question one, data demonstrates a statistically significant, moderate negative correlation between science teaching self-efficacy of participants interest in professional development about mathematics TEKS. Therefore, I reject the null hypothesis and can accept the alternative hypothesis only for science teaching self-efficacy and learning about mathematics TEKS. I failed to reject the null hypothesis for every other tested correlation.

Also of interest, although not statistically significant, as self-efficacy in teaching mathematics increases, interest in professional development in preparing students for achievement tests and in mathematical practices also increases. Additionally, as science teaching self-efficacy increases so does interest in interdisciplinary STEM learning. Alternatively, as science teaching self-efficacy decreases, interest in learning about science TEKS increases.

Research Question Two Results

RQ2: What are NEISD elementary teachers’ attitudes about 21st-century skills and how often do they report implementing integrative STEM?

To answer research question two, I analyzed the frequency data for attitudes about 21st-century learning and STEM instruction. I also investigated the median central tendencies of the data. Finally, I looked for trends or data that was inconsistent among the reported information.
The section on 21st-century learning attitudes prompted participants to respond on a Likert scale to, “I think it is important that students have learning opportunities to…” followed by 11 statements, including items such as “lead others to accomplish a goal,” “include others when making decisions,” and “choose which assignments out of many needs to be done first.” Participants chose between strongly disagree to strongly agree to each statement. Of all the T-STEM factors, teachers reported the highest level of agreement to the attitudes about 21st-century learning factor ($M = 4.6$ out of 5, $SD = 0.71$) as shown on Table 3.5. The frequency results for each of the individual items forming this factor are presented in Table 3.9.

Participants overwhelmingly showed agreement with all statements receiving 80% or more as agree or strongly agree. More than 75% of participants strongly agreed that students should have learning opportunities to produce high–quality work (86%), respect the difference of their peers (83%), work well with students from different backgrounds (80%), make changes when things do not go as planned (79%), manage their time wisely when working on their own (79%), and encourage others to do their best work (76%). Although many teachers report agreement with the remaining statements, relatively fewer respondents reported that they strongly agree that students should choose which assignment out of many needs to be done first (49%), followed by set their own learning goals (61%), lead others to accomplish a goal (61%), help their peers (69%), and include others’ perspectives when making decisions (70%).
Table 3.9
Participant Responses to Items Regarding 21st-century Learning Attitudes

<table>
<thead>
<tr>
<th>I think it is important that students have learning opportunities to…</th>
<th>Mdn</th>
<th>Strongly disagree = 1</th>
<th>Disagree = 2</th>
<th>Neither agree nor disagree = 2</th>
<th>Agree = 4</th>
<th>Strongly agree = 5</th>
<th>Non-Response</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce high quality work.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>0 0%</td>
<td>8 11%</td>
<td>60 86%</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respect the differences of their peers.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>0 0%</td>
<td>10 14%</td>
<td>59 83%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work well with students from different backgrounds.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>1 1%</td>
<td>11 16%</td>
<td>57 80%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make changes when things do not go as planned.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>1 1%</td>
<td>12 17%</td>
<td>56 79%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage their time wisely when working on their own.</td>
<td>5.0</td>
<td>2 3%</td>
<td>1 1%</td>
<td>0 0%</td>
<td>12 17%</td>
<td>56 79%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encourage others to do their best work.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>0 0%</td>
<td>15 21%</td>
<td>54 76%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Include others’ perspectives when making decisions.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>2 3%</td>
<td>17 24%</td>
<td>50 70%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help their peers.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>1 1%</td>
<td>19 27%</td>
<td>48 69%</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead others to accomplish a goal.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>1 1%</td>
<td>25 35%</td>
<td>43 61%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set their own learning goals.</td>
<td>5.0</td>
<td>2 3%</td>
<td>0 0%</td>
<td>1 1%</td>
<td>24 34%</td>
<td>43 61%</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choose which assignment out of many needs to be done first.</td>
<td>4.0</td>
<td>2 3%</td>
<td>1 1%</td>
<td>11 16%</td>
<td>22 31%</td>
<td>35 49%</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Next, I transition to look closely at responses to the elementary STEM instruction factor, which is a measure of integrated STEM instruction reported by teachers. Overall, teachers reported that elementary students engaged in integrated STEM skills slightly more than half the time \((M = 3.29, SD = 0.78)\) as shown in Table 3.5. The frequency results for each of the individual items forming this factor are presented in Table 3.10.

The items forming the elementary STEM instruction factor questioned participants about how often they report their students doing specific STEM-related activities. The subscale contained a prompt, “During elementary STEM instruction periods, how often do your students…” followed by 14 statements such as, “develop problem-solving skills through investigations” and “complete activities with a real-world context.” For each statement, participants selected from a scale of 1–5, coded 1 for never, and 5 for every time. Table 3.10 presents the frequency results for each of the individual items forming this factor.

Overall, 92% or more teachers report engaging in the activities listed in Table 3.10 during a STEM instruction period at least occasionally. The one exception was the item about whether students learn about careers related to instructional content. Approximately 14% of teachers reported that they never teach students about careers related to the instructional content during STEM instruction. Based on the data from this subscale, 80% of respondents reported that students worked in small groups usually or every time. Similarly, 76% reported that students engaged in content-driven dialogue usually or every time, and 68% reported that students completed activities in a real-world context usually or every time.
### Table 3.10

**Participant Responses to Items Regarding Elementary STEM Instruction**

<table>
<thead>
<tr>
<th>During elementary instruction periods, how often do your students…</th>
<th>Mdn</th>
<th>Never = 1</th>
<th>Occasionally = 2</th>
<th>About half the time = 3</th>
<th>Usually = 4</th>
<th>Every time = 5</th>
<th>Non–Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Work in small groups.</td>
<td>4</td>
<td>0 0%</td>
<td>2</td>
<td>3%</td>
<td>13</td>
<td>17%</td>
<td>35</td>
</tr>
<tr>
<td>Engage in content-driven dialogue.</td>
<td>4</td>
<td>1 1%</td>
<td>8</td>
<td>11%</td>
<td>9</td>
<td>12%</td>
<td>34</td>
</tr>
<tr>
<td>Complete activities with a real-world context.</td>
<td>4</td>
<td>1 1%</td>
<td>13</td>
<td>18%</td>
<td>19</td>
<td>14%</td>
<td>49</td>
</tr>
<tr>
<td>Use tools to gather data (e.g. calculators, computers, programs, scales, rulers, compasses, etc.)</td>
<td>3</td>
<td>6 8%</td>
<td>23</td>
<td>31%</td>
<td>18</td>
<td>24%</td>
<td>18</td>
</tr>
<tr>
<td>Make careful observations or measurements.</td>
<td>3</td>
<td>1 1%</td>
<td>25</td>
<td>34%</td>
<td>12</td>
<td>16%</td>
<td>28</td>
</tr>
<tr>
<td>Make predictions that can be tested.</td>
<td>3.5</td>
<td>1 1%</td>
<td>17</td>
<td>23%</td>
<td>19</td>
<td>26%</td>
<td>31</td>
</tr>
<tr>
<td>Choose the most appropriate method to express results (e.g. drawings, models, charts, graphs, technical language, etc.)</td>
<td>3</td>
<td>5 7%</td>
<td>20</td>
<td>27%</td>
<td>16</td>
<td>22%</td>
<td>27</td>
</tr>
<tr>
<td>Learn about careers related to the instructional content.</td>
<td>2</td>
<td>10 14%</td>
<td>29</td>
<td>39%</td>
<td>13</td>
<td>18%</td>
<td>16</td>
</tr>
<tr>
<td>Develop problem-solving skills through investigations (e.g. scientific, design or theoretical investigation).</td>
<td>3</td>
<td>2 3%</td>
<td>28</td>
<td>38%</td>
<td>16</td>
<td>22%</td>
<td>23</td>
</tr>
<tr>
<td>Recognize patterns in data.</td>
<td>4</td>
<td>2 3%</td>
<td>20</td>
<td>27%</td>
<td>13</td>
<td>18%</td>
<td>34</td>
</tr>
<tr>
<td>Reason quantitatively.</td>
<td>3</td>
<td>4 5%</td>
<td>19</td>
<td>26%</td>
<td>15</td>
<td>20%</td>
<td>31</td>
</tr>
<tr>
<td>Create reasonable explanations of results of an experiment or investigation.</td>
<td>4</td>
<td>5 7%</td>
<td>19</td>
<td>26%</td>
<td>11</td>
<td>15%</td>
<td>35</td>
</tr>
<tr>
<td>Reason abstractly.</td>
<td>3</td>
<td>3 4%</td>
<td>20</td>
<td>27%</td>
<td>19</td>
<td>26%</td>
<td>28</td>
</tr>
<tr>
<td>Critique the reasonings of others.</td>
<td>3</td>
<td>4 5%</td>
<td>27</td>
<td>37%</td>
<td>14</td>
<td>19%</td>
<td>25</td>
</tr>
</tbody>
</table>

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Based on teachers’ reported STEM instruction data, respondents report their students usually to every time have students make predictions that can be tested (50%), reason abstractly (43%), use tools to gather data (36%), choose the most appropriate method to express results (45%), and develop problem-solving skills through investigation (38%). The activities with the most responses of occasionally or never were learn about careers related to the instructional content with 53%, critiquing the reasoning of others with 42%, develop problem-solving skills through investigations with 41%, use tools to gather data with 39%, make careful observations or measurements with 35%, choose the most appropriate method to express results with 34%, create reasonable explanations of results of an experiment or investigation with 33%, and reason abstractly with 31% of student never or occasionally having opportunities to do so.

In addition to frequency, I report the median central tendency response to each statement as another way to examine teachers’ implementation of specific practices during STEM instructional periods. The statement with the lowest central tendency (Mdn = 2) was learn about careers related to instructional content, which suggests it is done occasionally, on average. Five statements had the highest median response of 4, suggesting they are done usually, on average: work in small groups, engage in content-driven dialogue, complete activities in a real-world context, recognize patterns in data, and create reasonable explanations of results of an experiment or investigation.

To summarize the notable results for research question two, when reporting their attitudes towards 21st-century learning skills, 80% of respondents strongly agreed with three items: students should produce high quality work, respect the differences of their peers, and work well with students from different backgrounds. Also interesting was that
83% of respondents reported they *strongly agree* that students should have opportunities to respect the differences of their peers, but 42% report they *occasionally or never* have students engage in this activity by critiquing the reasoning of others.

*Research Question Three Results*

RQ3: Do hours of STEM-related professional development, science and mathematics teaching self-efficacy, and technology use predict elementary teachers’ STEM instruction scores?

To answer research question three, it was necessary to complete a multiple linear regression. It was necessary to ensure that certain assumptions were true before test statistics can be taken at face value and interpreted properly (Field, 2018). Once I confirmed that there were no violations, I ran a multiple linear regression to determine if the four independent variables were good predictors of elementary teachers’ STEM instruction score.

*Checking assumptions for research question three.* To run a multiple linear regression analysis, I checked that the data met the six most important assumptions (Field, 2018). The six tests were linearity of variables, normality of residuals, little or no evidence of multicollinearity, less than 1% of overly influential cases, independent errors, and homoscedasticity. A scatterplot of residual errors and the standardized predicted values of the outcome is “useful for testing assumptions of independent errors, homoscedasticity, and linearity” (Field, 2018, p. 301). The output used to investigate statistical assumptions for multiple linear regression is in Appendix I.

First, I examined the assumption of linearity using scatterplots. The scatterplots in Appendix I indicate a positive linear relationship between the dependent variable, STEM instruction score with the following predictor variables: STEM professional development
hours, science teaching self-efficacy, mathematics teaching self-efficacy, and student technology use (see Figures I.2–I.5).

Second, I examined the assumption of normality of standardized residuals using a histogram of residuals. The STEM instruction score histogram of residuals appears to be approximately normally distributed, bell-shaped, and symmetrical (see Figure I.6). I also used a P–P plot of standardized residuals to examine the linearity of relationships between predictors and the dependent variable (see Figure I.7). The P–P plot indicates a high probability that the variables are linear as most of the data points follow the diagonal line (Field, 2018).

Third, I checked for evidence of multicollinearity using the VIF and tolerance values (see Table 3.11). The VIF and the tolerance values indicate if a predictor is strongly related to another predictor (Field, 2018). The average VIF was 1.27, which is not “substantially greater than 1,” therefore there is no indication of a potentially biased regression model (Field, 2018). As all VIF values were less than 10 and all tolerance statistics were greater than .2, multicollinearity did not appear to be a problem (Field, 2018).

Table 3.11

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tolerance</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Self-efficacy</td>
<td>.79</td>
<td>1.26</td>
</tr>
<tr>
<td>Mathematics Self-efficacy</td>
<td>.82</td>
<td>1.22</td>
</tr>
<tr>
<td>STEM PD Hours</td>
<td>.79</td>
<td>1.27</td>
</tr>
<tr>
<td>Student Technology Use</td>
<td>.76</td>
<td>1.31</td>
</tr>
</tbody>
</table>
Fourth, to examine the presence of outliers and overly influential cases, I reviewed casewise diagnostics, Cooks’ distance values, and the residuals scatterplot (see Figure L.8). All cases of standardized residuals fell within -3 and 3 standard deviations, so SPSS did not produce a casewise diagnostics table. I confirmed that the maximum standardized residual was 2.16 and the minimum was -1.81. The maximum Cook’s distance value of 0.32 was less than one, indicating that no case is overly influential (Field, 2018).

Fifth, I checked the assumption of independent errors using Durbin-Watson. Errors between 1 and 3 are not typically concerning, so the assumption of uncorrelated errors is supported (Field, 2018). The Durbin-Watson statistic of 1.82, therefore, supports the assumption of uncorrelated errors. The scatterplot of residuals also supports the assumption of independence as the dots represent a random array. This is “indicative of a situation in which the assumptions of linearity and homoscedasticity have been met” (Field, 2018, p. 314).

Lastly, I checked the assumption of homoscedasticity using a scatterplot of standardized residuals (see Figure I.8). The assumption of homoscedasticity is that the variance is equal for all values of the predicted dependent variable implied by randomly scattered data points. Figure I.8 demonstrated homoscedasticity, as assessed by visual inspection of a plot of standardized residuals. Given that all the assumptions for multiple linear regression were supported, I proceeded with conducting multiple linear regression.

Answering research question three. For research question three, I examined whether a teacher’s hours of STEM-related professional development, science teaching self-efficacy, mathematics teaching self-efficacy, and student technology use statistically
significantly predicted their STEM instruction score using multivariate linear regression. A teacher’s STEM instruction score reflects the frequency with which their students utilize problem-solving skills through investigations, complete activities in a real-world context, recognize patterns in data, in addition to other relevant activities (Friday Institute for Educational Innovation, 2012b; see Table 3.10 for the individual items). I interpreted the standard regression coefficients and structure coefficients to measure the importance of variables. Standardized regression coefficients focus on the relationships among all variables and divides predictive credit for any shared variance among the predictor variables (Thompson, 2006). Structure coefficients quantify the relationship between each predictor variable to the outcome variable while indirectly accounting for all the other predictor variables (Yeatts et al., 2017).

It is important to ensure that there is a good model fit. STEM professional development hours, science teaching self-efficacy, mathematics teaching self-efficacy, and frequency of student technology use accounted for approximately 36% of the variation in teachers’ STEM instruction score ($R^2 = .36$). This data suggests that 64% of the variation is unaccounted for and may be explained by other variables. The adjusted $R^2$ of .31 means that there would be 5% less variance in the outcome if the whole population was used rather than a sample ($.36 – .31 = .05$) to determine the outcome (Field, 2018).

The model was a statistically significant predictor and indicates that teachers’ STEM instruction score is significantly predicted by teachers’ hours of STEM-related professional development, science teaching self-efficacy, mathematics teaching self-efficacy, and student technology use, $F(4, 46) = 6.49, p < .001$. This data indicates that the model is statistically significantly better at predicting the STEM instruction score than
the teachers’ mean STEM instruction score, and therefore I rejected the null hypothesis. The standardized coefficient Beta with the largest absolute value shows which independent variable has the greatest relative predictability for the dependent or outcome variable, STEM instruction score. The variable in the model that is the best predictor of a teacher’s STEM instruction score was student technology use (standardized $\beta = .48$) as shown in Table 3.12. This variable was also a statistically significant predictor ($p = .001$) of the dependent variable. STEM-related professional development was a poor predictor of a teacher’s STEM instruction score with a standardized $\beta = .13$ and was not statistically significant with $p = .341$. Science and mathematics teaching self-efficacy were both poor predictors of STEM instruction scores according to the standardized coefficients ($\beta = .08$ and $\beta = .09$, respectively) and were not statistically significant ($p = .541$ and $p = .457$, respectively).

The linear regression model can be represented with an equation using the unstandardized beta coefficients. Table 3.12 also reports the unstandardized beta coefficients, which are used to show the change in STEM instruction score for each unit change of the independent variable (Laerd Statistics, 2015). The equation used to illustrate the impact of science self-efficacy, mathematics self-efficacy, student technology use, and STEM-related professional development on teachers’ STEM instruction scores is below:

$$\text{STEM instruction score} = 15.15 + .12 \text{ (science teaching self-efficacy)} + .18 \text{ (mathematics teaching self-efficacy)} + .66 \text{ (student technology use)} + .24 \text{ (STEM-related professional development)}$$

The only individual statistically significant predictor is student technology use ($\beta = .66$, $p < .001$).
Table 3.12

Predictor Regression Coefficients for Outcome – STEM Instruction Score

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Unstandardized Beta Coefficient (B)</th>
<th>Coefficients Std. Error (SE B)</th>
<th>Standardized Beta Coefficient</th>
<th>Lower CI</th>
<th>Upper CI</th>
<th>r</th>
<th>Structure Coefficient ( r_s )</th>
<th>Squared Structure Coefficient ( r_s^2 )</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>15.15</td>
<td>11.57</td>
<td>−8.14</td>
<td>38.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.197</td>
</tr>
<tr>
<td>Science teaching Self-efficacy</td>
<td>.12</td>
<td>.19</td>
<td>.08</td>
<td>−.26</td>
<td>.49</td>
<td>.24</td>
<td>.40</td>
<td>.16</td>
<td>.621</td>
<td>.541</td>
</tr>
<tr>
<td>Mathematics teaching Self-efficacy</td>
<td>.18</td>
<td>.24</td>
<td>.09</td>
<td>−.31</td>
<td>.67</td>
<td>.19</td>
<td>.32</td>
<td>.10</td>
<td>.75</td>
<td>.457</td>
</tr>
<tr>
<td>Student Technology Use</td>
<td>.66</td>
<td>.19</td>
<td>.48</td>
<td>.28</td>
<td>1.05</td>
<td>.57</td>
<td>.96</td>
<td>.91</td>
<td>3.46</td>
<td>.000</td>
</tr>
<tr>
<td>STEM-related Prof. Development</td>
<td>.24</td>
<td>.24</td>
<td>.13</td>
<td>−.26</td>
<td>.73</td>
<td>.38</td>
<td>.63</td>
<td>.40</td>
<td>.96</td>
<td>.341</td>
</tr>
</tbody>
</table>

Notes. Model \( R^2 = .36 \), Model \( R = .6 \). To aid in interpretation of the regression equation, this regression analysis used the total sum scores (i.e., not the averaged scale score) for the predictor scales and the outcome STEM instruction score scale.
This multiple linear regression equation aids in interpreting the results for each predictor. According to Field (2018), “the size of the $\beta$ indicated the degree to which each predictor affects the outcome if the effects of all other predictors are held constant” (p. 306). For example, for every 1 point increase on the sum total of the science teaching self-efficacy scale, the model predicts a 0.12 point increase in the STEM instruction score, when all other values for predictor variables in the model are held constant. For every 1–point increase on the mathematics teaching self-efficacy scale, the model predicts a 0.18 point increase in the sum total of the STEM instruction scaled score if all other predictor variable values remain constant. For every 1 point increase on the sum total of the student technology use scale, the model predicts a 0.66 point increase in the summed STEM instruction score, when all other values for predictor variables in the model are held constant. For every 1 hour increase on the scale for STEM-related professional development, the model predicts a 0.24 point increase in the summed STEM instruction scale score, holding all other predictor variables constant.

The linear regression model can also be interpreted by examining the structure coefficients, which are the bivariate correlation between each predictor and the synthetic $Y$ variable (Kraha et al., 2012; Thompson, 2006). Examining structure coefficients along with $\beta$–weights provides a more complete analysis of the predictive efficacy of each predictor variable because $\beta$ weights alone represent the correlation between each predictor and the outcome variable only if all predictors are perfectly uncorrelated, which will never occur in real-world situations (Courville & Thompson, 2001; Yeatts et al., 2017). In reality, predictors explain the same variance in the outcome variable, so the shared variance is not equally distributed among $\beta$–weights (Courville & Thompson,
A result, according to Yeats et al. (2017) is that “β weights become increasingly unreliable when predictor variables are correlated, which is often the case in social sciences” (p. 83). Accordingly, structure coefficients improve the accuracy of interpretation by taking into account the multicollinearity of predictor variables. The squared structure coefficient explains the unique proportion of model variance or the explained effect of the model $R^2$ for that variable itself. This means that if the sum of the squared structure coefficients exceeds 1, multicollinearity is present. Likewise, if the sum of the squared structure coefficients for any two variables exceeds 1, there is multicollinearity between the two variables. For this regression model, the sum of the squared structure coefficients is 1.57, indicating multicollinearity in predicting the outcome of teachers’ reported frequency of STEM implementation.

Examination of structure coefficients of the data confirms that student technology use contributed most to the variance with the largest absolute value among the predictor variables ($r_s = .96, r_s^2 = .91$). As the sum of the squared structure coefficients of student technology use ($r_s^2 = .91$) and any other single variable exceeds 1, student technology use is correlated with every other variable in the model. Structure coefficients for science teaching self-efficacy ($r_s^2 = .16$) and mathematics teaching self-efficacy ($r_s^2 = .10$) showed very minimal correlation between either predictor variable and student technology use. Science teaching self-efficacy proved to have a larger correlation than mathematics teaching self-efficacy when examining structure coefficients whereas the standardized β-weight for mathematics was slightly higher than science teaching efficacy, meaning that the standardized β-weight slightly overestimated the contribution of mathematics teaching self-efficacy. The sum of the squared structure coefficients for
student technology use \( (r_s^2 = .91) \) and hours of STEM-related professional development \( (r_s^2 = .40) \) is greater than 1.00 \( (0.91 + 0.40 = 1.31) \), which implies that the two predictors are multicollinear and explain some of the same part of the STEM instruction score (Henson, 2002b; Kraha et al., 2012).

**Summary of Results**

The results from research question one showed that a teacher’s self-efficacy in teaching mathematics and teaching science has very little relationship with their interest in professional development related to STEM topics. The only statistically significant correlation among teaching self-efficacy in mathematics or science was a moderate negative correlation between science teaching self-efficacy and learning about mathematics TEKS, \( t_b = -.24, p = .02 \). No other statistically significant relationship existed between mathematics or science teaching self-efficacy and any STEM-related professional development topics.

I used research question two to examine teachers’ attitudes about students learning 21st-century skills and the frequency of their integrative STEM instructional practices. Examples of 21st-century skills include making changes when things do not go as planned and encouraging peers. Examples of STEM instructional practices include working in small groups and reasoning quantitatively. Over 90% of teachers agreed or strongly agreed that 21st-century skills are important for students to learn, the only exception being choose which assignment out of many needs to be done first (80%). The three highest–rated skills that students should practice were opportunities to produce high–quality work, respect the difference of their peers, and work well with students from different backgrounds. Conversely, when reporting about their actual STEM teaching
practices, 42% report they never or occasionally provide students opportunities to engage in conversation in which they critique the reasoning of others.

Results for research question three showed whether four variables predicted a teacher’s STEM instruction score. Collectively, mathematics teaching self-efficacy, science teaching self-efficacy, student technology use, and hours of STEM-related professional development are statistically significant predictors of a teacher’s STEM instruction score $F(4, 46) = 6.49, p < .001$. Furthermore, hours of STEM-related professional development, science teaching self-efficacy, mathematics teaching self-efficacy, and student technology use account for 36% of the variation in reported integrated STEM instruction among participants ($R^2 = .36$). Student technology use was the most prominent individual predictor of a teacher’s STEM instruction score and the only statistically significant predictor variable. Based on the analysis of squared structure coefficients, the variable, student technology use, showed slight multicollinearity with science and mathematics teaching self-efficacy and high multicollinearity with hours of STEM-related professional development in predicting the STEM instruction score when considered independently from the other predictor variable. This means that the statistically significant standardized $\beta$–weight for student technology use overestimated the contribution of that variable itself and hours of STEM-related professional learning was somewhat underestimated in the regression model. Mathematics self-efficacy, and science self-efficacy were not strong predictors of STEM instruction scores individually.

Discussion

This quantitative study provided data on teaching self-efficacy about elementary educators in Northeast Independent School District (NEISD) elementary classrooms and
their STEM instruction. This study focused on identifying the teaching self-efficacy of elementary educators in NEISD elementary classrooms and identifying variables that might predict their STEM instruction. In the following section, I discuss the results of this study as they connect to relevant literature and Bandura’s (1978) theory of self-efficacy.

Teaching Self-Efficacy and Interest in STEM-related Professional Development

Self-efficacy in mathematics and science did not significantly correlate with interest in STEM-related professional development. Participants reported feeling efficacious in teaching mathematics with an average score of 4.16 out of 5, which was slightly higher than their average science self-efficacy score of 3.84. Based on research question one results, mathematics and science teaching self-efficacy were weakly to very weakly positively or negatively related to elementary teachers’ interest in STEM-related professional development. This is consistent with Biscoe’s (2017) study of grades K-8 science teachers, which revealed no statistically significant relationship between science teaching self-efficacy and other factors, including hours of professional development. Biscoe (2017) reported a very small effect size of 0.084, indicating that science self-efficacy had a very weak correlation with a participants hours of STEM-focused professional development. Most participants in the current study reported interest in STEM-related professional development. Over 50% of participants reported they were definitely interested in six of the topics from the instrument, including using real-world issues to teach (64%), instructional strategies for meeting the needs of diverse learners (58%), integrating literacy into STEM instruction (55%), use of education technology to support learning (54%), problem-based learning (53%), and integrating science, technology, engineering, and mathematics (52%). Elementary participants of Owens’s
(2018) MO-STEM agreed that using real-world issues was of the highest interest for professional development topics, in addition to using educational technologies to support learning, strategies for student use of mobile technologies, instructional strategies for meeting the needs of diverse learners, and aligning instruction and curriculum with standards. Results from NEISD teachers showed some similarities and some differences with other MO-STEM data which reported that elementary teachers are most interested in mathematical practices, aligning instruction and curriculum with standards, and learning new state standards (Assessment Resource Center, 2016).

Given the generally high interest in STEM-related professional development among participants, I can conclude that regardless of their self-efficacy, most NEISD participants are interested in attending STEM professional development. In other words, if more high-quality professional development were offered, the results suggest that most elementary teachers would be interested in attending, especially if it covered topics like using real-world issues to teach, instructional strategies for meeting the needs of diverse learners and using education technology to support learning. This data can be taken in context with the literature, which cites a lack of quality professional development as a hindrance to integrated STEM instruction (Brophy et al., 2008; Fenton & Essler–Petty, 2019). Margot and Kettler (2019) synthesized 25 articles for thematic analysis on STEM integration and reported that the “most often mentioned support that would increase the effectiveness of STEM education was learning opportunities for teachers to increase their ability to effectively integrate STEM content into their curriculum” (p. 14). The perceived value of STEM learning opportunities for teachers by Margot and Kettler is consistent with the conclusion from Owens (2018) and the current study that regardless
of their self-efficacy, most teachers are interested in attending STEM professional development.

Factors Predicting Elementary Teachers’ STEM Integrated Teaching

A regression model determined that hours of STEM-related professional development, mathematics teaching self-efficacy, science teaching self-efficacy, and students’ technology use in the classroom collectively predicted the frequency of elementary teachers’ STEM instruction. Of those variables, student technology use was the most prominent predictor of a teacher’s integrated STEM instruction and was the only statistically significant predictor variable in research question three. This finding showed that teachers who reported more frequent use of technology in class significantly predicted their frequency of exposing students to STEM instruction ($\beta = .66, p < .001$). This result was not surprising as student technology use was shown to align with integrated STEM instruction in the literature as well (Al Salami et al., 2017; Lim et al., 2013; O’Neal et al., 2017). This finding may also imply that teachers who are open to innovative technology use and attend more STEM professional development are also willing to explore STEM integration.

Innovative teaching practices, such as incorporating student technology use, often require teachers to leave their comfort zones (Baker & Galanti, 2017; Parker et al., 2015; Smith et al., 2018). Teachers willing to do so likely believe that their students, however young, can engage in student-centered learning without constant, explicit guidance from a teacher (National Academies of Sciences, Engineering, and Medicine, 2021). Results in the current research affirm that teachers willing to allow students to use technology are more inclined to attempt and explore STEM instruction.
Hours of STEM-related professional development, while not statistically significant, was the second strongest predictor of teachers’ reported STEM instruction score ($\beta = .24, p = .341$). The analysis of squared structure coefficients revealed that the variable, student technology use, showed high multicollinearity with hours of STEM-related professional development in predicting the STEM instruction score when considered independently from the other predictor variable. This means that the statistically significant standardized $\beta$–weight for student technology use overestimated the contribution of that variable, and hours of STEM-related professional learning was somewhat underestimated in the regression model. The finding that hours of STEM-related professional development is positively related with STEM instruction is also supported by other research. For example, upon participating in integrative STEM professional development, participants reported a subsequent increase in the STEM instruction and overall student engagement (Al Salami et al., 2017; Faber et al., 2013; Nadelson et al., 2013).

Self-efficacy in specific content areas is an important factor that has been shown to impact teachers’ classroom practices and quality of instruction (Biscoe, 2017; Briley, 2012; Catalano et al., 2019; Dilekli & Tezci, 2016). The current study found that science teaching self-efficacy and mathematics teaching self-efficacy were not statistically significant predictors of integrated STEM instruction as individual variables but did have a small contribution to a statistically significant regression model. Other research may support conclusions of a stronger relationship between teaching self-efficacy and STEM instruction. For example, many previous studies reported a positive correlation between self-efficacy in teaching mathematics and science and integrative STEM instruction.
(Buechel, 2021; Donnelley Smith, 2018; Han et al., 2021; Prentiss Bennett, 2016; Sloane, 2019). Furthermore, researchers who used the T-STEM instrument identified a significant direct effect of high school teacher self-efficacy on students’ STEM achievement (Han et al., 2021). Faber et al. (2013) found that as teachers’ self-efficacy increased, their instructional practices improved. T-STEM data from the current study were not consistent with others’ results.

21st-Century Skills and Integrative STEM Instruction

Participants in this study overwhelmingly agreed on the importance of students learning 21st-century skills. Over 80% of participants agreed or strongly agreed with all items from the 21st-century learning attitudes instrument. The results of this study are consistent with prior literature regarding the value placed on 21st-century learning among educators (Akcanca, 2020; Bellanca, 2010; Han et al., 2021; O’Neal et al., 2017). Teachers also understand the need for students to acquire 21st-century skills early during their education (O’Neal et al., 2017; Saavedra & Opfer, 2012). Various studies contend that 21st-century skills are not contextualized in a single subject or integrated STEM, which leaves the application open to any part of students’ learning. Leaders in STEM education include these skills among the important elements of effective STEM curricula (Akcanca, 2020; Bybee, 2010; Holmlund et al., 2018; Kelley & Knowles, 2016; Vasquez, 2015).

However, participants of the current study do not associate 21st-century skills with integrative STEM instruction, which contradicts other literature (Akcanca, 2020; Han et al., 2021; Perdana et al., 2021). Pearson’s $r$ correlation analyses indicated a very weak negative association ($r = -.04$) between elementary STEM instruction ($M = 3.29,$
SD = 0.78) and 21st-century skills (M = 4.6, SD = 0.71), which was not statistically significant. These results imply that teachers in the current study value 21st-century skills but do not associate these skills with STEM activities. It also suggests that elementary teacher participants value 21st-century skills to a greater degree than they are willing to implement instructional activities in the classroom that may cultivate these 21st-century skills. Literature, however, suggests that these go hand-in-hand (Akcanca, 2020; Perdana et al., 2021).

I expected to find parallels between teachers’ attitudes about 21st-century skills and their integrative STEM practices. Surprisingly, there were more contrasts than parallels in teachers’ reported attitudes and their actual teaching practices. While 83% of respondents strongly agreed that students should have opportunities to respect the differences of their peers, only 5% provided students opportunities to critique the reasoning of others every time during instruction. Although 79% of teacher participants strongly agreed that students should learn to make changes when things do not go as planned but only 7% reported creating opportunities for students to develop problem-solving skills through investigations every time during instruction. Similarly, 70% strongly agreed that students should have opportunities to include others’ perspectives when making decisions, but 31% reported their students never or only occasionally reason abstractly during instruction. In sum, participants reported they value 21st-century skills but may not value these skills enough to update how they teach to cultivate those valued skills.
Implications and Recommendations

The following sections detail implications and recommendations for district and elementary school administrators, professional development leaders, classroom educators, educators in preservice teacher programs, and researchers interested in improving integrative STEM in elementary classrooms. Elementary educators are charged with the substantial task of sparking the interest of young learners in STEM fields that can lead to more of these learners pursuing STEM education and STEM degrees (Dejarnette, 2012; Early Childhood STEM Working Group, 2017; Will, 2018).

District and Elementary School Administrators

Public elementary school administrators are the instructional leader of their schools (Atasoy, 2020). To insight a positive change in elementary campuses regarding STEM instruction, administrators must do more than encourage teachers to do it. The current study did not find a strong correlation between teaching self-efficacy in STEM content areas and integrative STEM practices, but student technology use significantly predicted teachers’ integrative STEM practices. Additionally, hours of STEM professional development also predicted the frequency of teachers’ integrative STEM practices. All elementary teachers must feel supported in updating the ways they teach. I recommend that administrators engage in the following six items to promote a culture of innovative STEM practices: (a) prioritize innovative teaching practices, (b) provide professional development in STEM that aligns with state standards, (c) ensure teachers understand what constitutes integrative STEM, (d) create access to integrated STEM resources, (e) appoint a STEM coordinator to facilitate, manage, and support teachers in
their STEM education endeavors, and (f) encourage and support student technology use in the elementary classrooms.

By creating a culture that values innovation and providing professional development in integrative STEM, administrators are sending a message that STEM is a priority and teachers are supported in their endeavors to implement STEM. Integrative STEM is not additional content for teachers to fit into their schedules. It is possible to take current standards and integrate the content in ways that align with current best teaching practices. If teachers feel like STEM is just another optional initiative, most are not inclined to voluntarily add more to their teaching responsibilities. Therefore, administrators must clearly define and explain integrative STEM, so teachers understand all the benefits and that integrative STEM does not add to one’s current responsibilities.

Professional Development Leaders

In this quantitative study, I found that over 50% of participants reported they are definitely interested in six of the STEM-related professional development topics, including using real-world issues to teach, interdisciplinary STEM, and integrating literacy into STEM instruction. This is consistent with other researchers who indicate that teachers have limited STEM knowledge and even less exposure to STEM professional development (Estapa & Tank, 2017; Kuehnert et al., 2019; Owens et al., 2018). Teachers need to learn to teach STEM, but STEM professional development must be offered that is meaningful and presented in ways conducive to how the teachers want to learn (Chval et al., 2008; Desimone & Garet, 2015; Shernoff et al., 2017). If teachers learn about STEM topics of interest in ways that align with best andragogical practices, their learning is
more likely to be implemented in their classrooms (Baxter et al., 2014; Desimone et al., 2002).

The majority of training in-service teachers receive is through professional development offered by experts in their field (Desimone & Garet, 2015; Guskey, 2002). If districts do not have STEM specialists, instructional leaders must learn integrative STEM practices to model for classroom teachers. Professional development leaders must do what classroom teachers are expected to do, which is innovate their teaching practices and meet the individual needs of their learners. This is more than learning new state standards and online assessments. Professional development leaders need to integrate STEM into their professional development sessions and show how it can replace some current outdated practices.

*Classroom Educators*

Teachers impact the attitudes and beliefs of students. Teachers do not need to be STEM experts. Still, they need to understand that their attitudes about STEM affect learners’ attitudes about STEM. It is imperative that teachers model the 21st-century skills they agree, according to the results of this research, are important for their students to learn. Teachers should embrace their own mistakes as opportunities to make changes and learn. Teachers should set their own learning goals and work towards achieving those goals. Similar to STEM, 21st-century skills such as setting goals is about persevering through challenges, exploring different approaches, and seeking out assistance when necessary. This is true for adults and children. Teachers should be afforded opportunities to do during professional development.
To incite a positive change in how students learn, teachers need to seek out professional development that aligns with best teaching practices, including those highlighted in the professional development topics in this study. Texas does not mandate STEM education in K–5 classrooms (TEA, 2022c). School districts prioritize teacher training based on the TEKS and, more specifically, standardized accountability testing. If teachers want to learn the best STEM teaching practices, they can seek it out themselves, or they can communicate to their district leadership the need to enhance their instruction with integrative STEM to meet the needs of their learners.

*Educators in Preservice Teacher Programs*

An important finding of this study relates to the negative correlation between teaching self-efficacy and interest in gaining knowledge about TEKS. Results of this study indicated that as elementary teachers develop their self-efficacy in teaching, they tend to be less interested in learning foundational content knowledge. Educators in preservice teachers programs can help aspiring teachers to develop their self-efficacy in content knowledge in ways that also provide exposure to integrative STEM practices.

Preservice teachers are exploring and experimenting with teaching practices, while in-service teachers are bound to state and district mandates. Teacher preservice programs should introduce integrative STEM to aspiring teachers so there is a foundation on which quality teaching practices can be built. A better scenario includes professional classroom educators modeling integrative STEM, and additional opportunities for preservice teachers to experience planning and implementing integrative STEM, followed by discussion and reflection. Whatever the case, preservice teachers should be exposed to
the essential elements of integrative STEM as much as possible and understand their value in the context of 21st-century skills, learning standards, and STEM content.

Researchers

Results from this study aligned with results from prior studies that suggest that while elementary teachers value skills congruent with integrative STEM instruction, teaching practices are not consistent with these values (Partnership for 21st-century skills, 2007; Sloane, 2019). Limited research explores the relationship between integrative STEM practices with support from administrators and access to STEM resources. Therefore, future research should further explore elementary teachers’ STEM instructional practices and investigate other potential internal or external hindrances besides science and mathematics self-efficacy. It is essential that students are exposed to STEM early, therefore, it is crucial to clearly understand the factors that are interfering with this exposure so they can be mitigated. Further investigation might provide insight into the impediments of STEM instruction in elementary classrooms with the goal of uncovering areas to improve instruction to better prepare young learners to excel in STEM.

Summary and Conclusion

Despite a global economy in dire need of qualified STEM professionals, America is unable to retain its competitive stronghold in innovation and emerging industries (NSB, 2020). One remedy for this problem is to engage learners early and actively in integrative STEM (English, 2017; National Academies of Sciences, Engineering, and Medicine, 2021; NSB, 2010, 2022a; Will, 2018). While research reiterates this viable solution, Texas classroom teachers are not teaching integrative STEM as part of the daily
or weekly curriculum (Isabelle, 2017; Laksmiwati et al., 2020; Prentiss Bennett, 2016). Other states have established K–5 STEM and engineering standards, but Texas has yet to prioritize these skills as necessary instruction (TEA, 2022c). STEM is critical, and the purpose of this study was to identify the teaching self-efficacy of elementary educators in teaching science and mathematics, examine correlations between teaching self-efficacy of elementary educators in mathematics and science instruction with their interest in STEM-related professional development and to identify variables that predicted how often elementary teachers reported incorporating integrated STEM in their classrooms.

My research utilized a quantitative correlational cross-sectional survey. Results indicated that a teacher’s self-efficacy in teaching mathematics and teaching science has very little relationship with their interest in professional development related to STEM topics. Research question two results, regarding perceptions of 21st-century skills, indicated that participants rate them highly. Despite placing substantial value in students learning 21st-century skills, most teachers reported not providing many opportunities to practice them during STEM instruction. Research question three results indicated that STEM-related professional development hours, science teaching self-efficacy, mathematics teaching self-efficacy, and student technology use were predictors of teachers’ elementary STEM instruction score. Results of the multiple linear regression suggested that hours of STEM professional development, students’ technology use in the classroom, as well as science and mathematics teaching self-efficacy predicted teachers’ reported frequency of STEM instruction, with student technology use as the best predictor of the STEM instruction score.
Professional implications of the results from this study relate to Texas educators, administrators, professional development leaders, researchers, and elementary preservice programs with an interest in improving elementary teaching practices around integrative STEM. This study contributes to the current research regarding teaching self-efficacy in science and mathematics among elementary educators, STEM instruction in elementary classrooms, and STEM professional development interests of elementary classroom teachers. The results from this research can potentially impact decisions regarding what and how elementary teachers are trained, specifically in areas related to integrative STEM. Additionally, the results from this study can guide leaders of elementary teacher preservice programs to make a cognizant effort to explicitly include STEM and 21st-century skills as part of the preservice or practicum experience. Finally, implications exist for future research to examine other internal external factors that might impact elementary teachers’ integrative STEM teaching practices. The following chapter includes the executive summary and a findings distribution proposal.
CHAPTER FOUR

Executive Summary and Distribution of Findings

Executive Summary

For over two decades, STEM education has been a global priority. Despite the growing demand for a STEM-literate workforce, the supply of capable American professionals has not kept up with the demand (English, 2016; Kocabas et al., 2020; NSB, 2022b). Recent reports suggest that more American jobs, even skilled technical jobs not requiring college degrees, are being filled by international workers (NSB, 2022a). Studies suggest this shortage of STEM-qualified workers has origins in K–12 education (Doerschuk et al., 2016; English, 2016; Holmlund et al., 2018; NSB, 2022b; President’s Council of Advisors on Science and Technology, 2010).

The pursuit of challenging STEM courses in high school can be traced to exposure and interest as early as preschool with strong links to upper–elementary integrative STEM instruction (Clayton, 2019; Early Childhood STEM Working Group, 2017; Estapa & Tank, 2017; Lange et al., 2021; Will, 2018). Although there is a need for exposure to STEM early, integrative STEM instruction does not consistently occur in elementary classrooms, it is not required instruction in most states, and few schools provide adequate training and resources to make it practically applicable (Archer et al., 2012; Dejarnette, 2012; Schmidt & Shumow, 2014). Elementary teachers understand the importance of STEM (Hammack & Ivey, 2019; Laksmiwati et al., 2020; Smith et al., 2015), and while the above factors hinder integrative STEM instruction, it is important to understand the specific reasons that teachers are not regularly teaching STEM (Douglas...
In understanding the impediments to integrative STEM instruction, state and district officials can adjust priorities to create a culture that embraces STEM instruction in elementary classrooms.

The purpose of this quantitative correlational cross-sectional survey research was trifold. The first purpose of this survey was to examine correlations between teaching self-efficacy of elementary educators in mathematics and science instruction with their interest in STEM-related professional development. The second purpose was to understand their attitudes about 21st-century learning skills and their integrative STEM teaching practices. The third purpose was to examine if elementary teachers’ reported teaching self-efficacy, technology use, and hours of STEM professional predicted how often they reported incorporating integrated STEM in their classrooms. The research questions that guided this quantitative study were:

1. What are NEISD elementary teachers’ self-efficacy in teaching mathematics and science and how does this teaching self-efficacy correlate with their interest in STEM-related professional?

2. What are NEISD elementary teachers’ attitudes about 21st-century skills and how often do they report implementing integrative STEM?

3. Do hours of STEM-related professional development, science and mathematics teaching self-efficacy, and technology use predict elementary teachers’ STEM instruction score?

Overview of Data Collection and Analysis Procedures

Through this quantitative correlational study, I utilized a cross-sectional survey design to investigate NEISD elementary teachers’ teaching self-efficacy, attitudes toward 21st-century learning, instructional practices, and interests in STEM professional development. Using the correlational design allowed me to explore the strength of the relationships (Creswell & Creswell, 2018) between self-efficacy in teaching mathematics
and science (Friday Institute for Educational Innovation, 2012c) with interest in STEM-related professional development as identified with a section of the MO-STEM instrument (Assessment Resource Center, 2016). I reported descriptive statistics on science teaching self-efficacy, mathematics teaching self-efficacy, student technology use, STEM instruction, and 21st-century learning attitudes using components of the T-STEM instrument (Friday Institute for Educational Innovation, 2012c) looked deeper at the frequency of responses for each of the items comprising two factors, attitudes about 21st-century learning and elementary STEM instruction. Finally, I also investigated whether the following four variables predicted a participant’s elementary STEM instruction score: hours of STEM-related professional development, mathematics teaching self-efficacy, science teaching self-efficacy, and student technology use.

Bandura’s (1997) self-efficacy theory served as a framework for this study. I chose this framework because it aligns with the purpose of this study was to identify the teaching self-efficacy of elementary educators in teaching science and mathematics, examine correlations between teaching self-efficacy of elementary educators in mathematics and science instruction with their interest in STEM-related professional development and to identify variables that predicted how often elementary teachers reported incorporating integrated STEM in their classrooms. Teacher self-efficacy in content areas has proven to relate positively to student motivation and achievement (Perera & John, 2020; Zee & Koomen, 2016). Self-efficacy for learning is also applicable to this study. Regarding 21st-century learning and integrative STEM, teachers’ self-efficacy for learning can impact their willingness to try innovative teaching practices (Bandura, 1990).
I used Kendall’s Tau $b$ to determine if a statistically significant relationship existed to answer research question one. I examined descriptive statistics to address research question two. For research question three, I used multiple linear regression to understand the relationship between four independent variables and the continuous dependent variable, elementary STEM instruction.

*Summary of Key Findings*

The correlation results from research question one suggests that a teacher’s self-efficacy in teaching mathematics and teaching science has very little relationship with their interest in professional development related to STEM topics. Overall teachers reported feeling confident in teaching mathematics with an average score of 4.16 out of five. The average science self-efficacy score was 3.84 out of five which suggests they are slightly efficacious in science. The only statistically significant correlation to any STEM-related professional development topic was a negative correlation between science teaching self-efficacy and learning about mathematics TEKS. Results for research question two showed that participants overwhelmingly agreed or strongly agreed with every item pertaining to their own attitudes towards 21st-century learning.

Results from the multiple linear regression for question three showed that the four predictor variables (mathematics teaching self-efficacy, science teaching self-efficacy, student technology use, and hours of STEM-related professional development) statistically significantly predicted teachers’ frequency of STEM instruction score and explain 36% of the variance of STEM instruction. Student technology use was the most prominent individual predictor of a teacher’s STEM instruction score and the only statistically significant predictor variable.
Implications and Recommendations

Students need to be STEM-literate. Elementary teachers, regardless of mathematics and science teaching self-efficacy, are interested in STEM-related professional development to prepare students to be STEM-literate. Professional implications of these results relate predominantly to elementary education administrators, professional development leaders, classroom teachers, and educators in preservice teacher programs.

Teachers are interested in STEM professional development, and reported significant increases in confidence, knowledge, and efficacy to teach integrative STEM after attending STEM professional development (Lesseig et al., 2016; Nadelson et al., 2013). Margot and Kettler (2019) conducted a literature review and found that the most mentioned support that would increase integrative STEM education was teacher learning opportunities. Therefore, to bring about positive change, administrators must make professional development available, professional development leaders must make learning opportunities purposeful, and classroom teachers must embrace integrative STEM instruction as a teaching method.

Student technology use was the only statistically significant individual predictor of a teacher’s STEM instruction score. While this is consistent with previous literature (Al Salami et al., 2017; Lim et al., 2013; O’Neal et al., 2017), future research should investigate this relationship further. Qualitative research that includes teacher testimonials on their teaching self-efficacy, student technology use, 21st-century skills, and STEM instruction will strengthen the research regarding integrative STEM in elementary classrooms.
Findings Distribution Proposal

This section provides an overview of my intent to distribute research findings. First, I discuss the target audience with the most opportunity to influence positive change in professional development practice. Then, I identify venues and methods for distribution that are best suited to meet the goal of disseminating the findings most effectively.

Target Audience

The target audience for distributing these research findings includes NEISD administrators, teacher trainers, and professional organizations including National Science Teacher Association, and School Science and Mathematics Association. District administrators throughout Texas are pressured to perform on state–mandated assessments and struggle to provide a more rigorous education with fewer resources (Ryan & Weinstein, 2009). They lose funding with every family that withdraws to send their children to charter and private schools. Equipped with these research findings, district leaderships can align federal and state initiatives with the specific needs of elementary educators to improve teacher self-efficacy in STEM content areas and reform outdated practices to create innovative learning experiences.

Teacher trainers in the district prepare and distribute professional development based on guidance from district leadership. Teacher trainers can immediately model innovative practices for teachers to integrate into their instruction while complying with district requirements. Transformation may take time but knowing specific areas of diminished self-efficacy among elementary educators provides a starting point.
State and national professional organizations in education will benefit from these research results. The current study confirms the results of other research about integrative STEM, teacher efficacy, and professional development. Generalizations from this research may apply to other districts and may help those responsible for planning professional development for a different community or more extensive organization.

*Proposed Distribution Method and Venue*

I distributed research results to professional development leaders through conference sessions at the National Science Teacher Association conference in July 2022 and the School Science and Mathematics Association conference in September 2022. I will continue to present the results of this study at future mathematics, science, and STEM conferences, particularly those focused on elementary education. A future publication in a peer-reviewed journal sharing research results will highlight challenges faced by classroom teachers to integrating STEM in elementary classrooms and potential avenues to increase STEM instruction. Research results will address the root of this problem which can be traced to elementary classrooms (Cotabish et al., 2013; Daugherty et al., 2014). Dissemination of research results will include best teaching practices and integrative strategies that teacher trainers can implement in their sessions (Havice et al., 2018).

*Conclusion*

This cross-sectional quantitative research explored the teaching self-efficacy of elementary teachers in mathematics and science and sought to identify variables that might predict STEM instruction. Although there is clearly a need for exposure to STEM early (Will, 2018), integrative STEM instruction does not consistently occur in
elementary classrooms (Schmidt & Shumow, 2014). Considering elementary classroom teachers are at the frontlines of preparing our future STEM workforce, it is imperative to understand predictors and potential hindrances to integrative STEM instruction. This study showed that a teacher’s self-efficacy in mathematics and science were not individual predictors of their STEM instruction and opens the door to other factors, including professional development and student technology use. This study contributes to a larger body of research regarding impediments to STEM instruction and informs professional learning for the effective integration of STEM education into elementary instruction.
APPENDICES
APPENDIX A

Research Approval From Northeast Independent School District

Dear Erika Neuman,

A review committee has evaluated your request to conduct research this school year at North East ISD regarding "STEM Integration in Elementary Classrooms: A Quantitative Study Exploring Impediments and Improvements."

The district approves this research at the district level only, meaning you may now approach the campus principal to inquire about campus participation. If the principal approves the research, please note the additional terms and conditions of this approval:

1. The study makes minimal interruptions to the regular school program and makes no undue demands upon the time of students, teachers, administrators, or other district personnel.
2. The study does not involve research during the first and/or last 30 days of the school year as determined by the adopted NEISD calendar.
3. The study is not scheduled during district-wide testing periods.
4. The district reserves the right to decline future solicitations for this project.

Please note – participation in your study by individual district personnel is strictly voluntary. A copy of this letter should accompany your solicitation to district personnel. Should you have questions or need additional information, please contact me at chflore@neisd.net or by telephone at (210) 407-0558.

Sincerely,

Chris Flores, M. Ed.
Research Analyst
Department of Performance and Planning

Cc:

Anthony Jarrett, Chief Instructional Officer
Rudy Jimenez, Chief of Schools & Leadership
Jennifer Gutierrez, Executive Director of Elementary Education
Susan Diaz, Ph.D., Executive Director of Secondary Education
Alex Vandell, Director of Performance and Planning
APPENDIX B

IRB Determination: Not Human Subjects Research (NHSR)

From: Jessica Trevino no-reply@irbnet.org
Subject: IRBNet Board Action
Date: April 14, 2022 at 10:50 AM

To: Erika Ap...

Please note that Baylor University Institutional Review Board has taken the following action on IRBNet:

Project Title: [187847-1] STEM Integration in Elementary Classrooms: A Quantitative Study Exploring Impediments and Improvements
Principal Investigator: Erika Neuman, Ed.D

Submission Type: New Project
Date Submitted: April 5, 2022

Action: RESEARCH - NOT HSR
Effective Date: April 14, 2022
Review Type: Administrative Review

Should you have any questions you may contact Jessica Trevino at jessica_j_trevino@baylor.edu.

Thank you,
The IRBNet Support Team

https://nam02.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.irbnet.org%2F&data=9A%7C01%7Cerika_neuman%40baylor.edu%7C%7Cf4c1d5a1540bcb8a9a18d1e2f27d%7C02%7C7b5s48235039139%7C1%7C63%7C7%7C8%7C3000&sfdata=E3qxAu9c1JKhCJH%2BYAvDzFbMN%2B0d9WJbM%2B9log%3D&reserved=0
Dear Inspirational Leaders,

As NEISD educators in an evolving world, it is imperative that we prepare our students to be capable, competitive leaders. This begins with adequately preparing our teachers to meet these needs as early as possible. To best accomplish this, we need to understand the teaching practices of elementary teachers in STEM integration, 21st-century learning, student technology use, and professional development interests. In addition, it is worth inquiring about teacher self-efficacy in mathematics and science.

To collect this data, we respectfully ask that you provide the survey link and message below to your faculty and encourage their participation to best meet their needs for support and professional development. The deadline to complete the survey is May 6, 2022.

Thank you for your leadership and enduring commitment to our students.

Respectfully,
Erika Neuman
5th grade teacher
Bulverde Creek
APPENDIX D

Email Request to Participants

Dear amazing teachers,

One of your fellow NEISD educators needs your input. What content would you like to learn during our district professional development? What format for professional development best suits you? With your insight, we can make PD more meaningful. Please complete the linked questionnaire as honestly as possible by May 6, 2022.

Thanks for all that you do!

Respectfully,
Erika Neuman
5th grade teacher
Bulverde Creek
APPENDIX E
Survey Instrument

Q1.1 I have read the information provided above and agree to participate in this research.

Neuman e consent form

- [ ] Yes
- [ ] No

Q2.1 Are you a Pre–K through grade 5 teacher in NEISD?

- [ ] yes
- [ ] no

Q3.1 Including this school year, how many years have you taught at the K–12 level?

<table>
<thead>
<tr>
<th>Years experience</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22</th>
<th>24</th>
<th>26</th>
<th>28</th>
<th>30</th>
</tr>
</thead>
</table>

Q3.2 How many hours of professional development in each of the following areas have you participated in over the last 12 months?

<table>
<thead>
<tr>
<th>Hours</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>
Q3.3 What is your highest level of education?

- Some college
- Bachelors degree
- Masters degree
- Doctoral degree

Q3.4 If applicable, in what specialty area is your degree?

- Science
- Mathematics
- Computer science or technology integration
- Other
- No area of specialization
Q3.5 What do you currently teach? Check all that apply.

- [ ] Pre–Kindergarten
- [ ] Kindergarten
- [ ] 1st grade
- [ ] 2nd grade
- [ ] 3rd grade
- [ ] 4th grade
- [ ] 5th grade
- [ ] Special education
- [ ] Gifted and talented

Q3.6 What subjects do you currently teach? Check all that apply

- [ ] Reading
- [ ] Language arts
- [ ] Mathematics
- [ ] Science
- [ ] Social studies
- [ ] Music
- [ ] Physical education
- [ ] Social emotional learning
Q3.7 Do you currently teach STEM?

- Yes
- No

Q3.8 You answered ‘${Q3.7/ChoiceDescription/5}’ to the previous question. What keeps you from teaching STEM?

Q3.9 You answered ‘${Q3.7/ChoiceDescription/4}’ to the previous question. How do you teach STEM?

Q3.10 Explain what STEM should look like in an elementary classroom.

Q4.1 Directions: Please respond to these questions regarding your feelings about your own teaching.
<table>
<thead>
<tr>
<th>I am continually improving my science teaching practice.</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree nor disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I know the steps necessary to teach science effectively.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am confident that I can explain to student why science experiments work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am confident that I can teach science effectively.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I wonder if I have the necessary skills to teach science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I understand science concepts well enough to be effective in teaching science.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Given a choice, I would invites a colleague to evaluate my science teaching.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am confident that I can answer students’ science questions.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>When a student has difficulty understanding a science concept, I am confident that I know how to help the student understand it better.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>When teaching science, I am confident enough to welcome student questions.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I know what to do to increase student interest in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q4.2

Directions: Please respond to these questions regarding your feelings about your own teaching.
<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree nor disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am continually improving my mathematics teaching practice.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I know the steps necessary to teach mathematics effectively.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am confident that I can explain to students why mathematics experiments work.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am confident that I can teach mathematics effectively.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I wonder if I have the necessary skills to teach mathematics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I understand mathematics concepts well enough to be effective in teaching mathematics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Given a choice, I would invite a colleague to evaluate my mathematics teaching.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am confident that I can answer students’ mathematics questions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When a student has difficulty understanding a mathematics concept, I am confident that I know how to help the student understand it better.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When teaching mathematics, I am confident enough to welcome student questions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I know what to do to increase student interest in mathematics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Q4.3**
Directions: Please answer the following questions about how often students use technology in settings where you instruct students. If the question is Not applicable to your situation, please select “Not Applicable.”
<table>
<thead>
<tr>
<th>During elementary instructional periods, how often do your students…</th>
<th>Never</th>
<th>Occasionally</th>
<th>About half the time</th>
<th>Usually</th>
<th>Every time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use a variety of technologies, e.g. productivity, data visualization, research, and communication tools.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use technology to communicate and collaborate with others beyond the classroom.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use technology to access online resources and information as a part of activities.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use the same kinds of tools that professional researchers use, e.g. simulations, databases, satellite imagery</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Work on technology–enhanced projects that approach real-world application of technology.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use technology to help solve problems.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use technology to support higher–order thinking, e.g. analysis, synthesis and evaluation of ideas and information.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use technology to create new ideas and representations of information.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q4.4
Directions: Please answer the following questions about how often students engage in the following tasks during your instructional time.

During elementary instructional periods, how often do your students…
<table>
<thead>
<tr>
<th>skill</th>
<th>Never</th>
<th>Occasionally</th>
<th>About half the time</th>
<th>Usually</th>
<th>Every time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop problem-solving skills through investigations (e.g. scientific, design or theoretical investigations).</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Work in small groups.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Make predictions that can be tested.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Make careful observations or measurements.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use tools to gather data (e.g. calculators, computers, computer programs, scales, rulers, compasses, etc.).</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Recognize patterns in data.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Create reasonable explanations of results of an experiment or investigation.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Choose the most appropriate method to express results (e.g. drawings, models, charts, graphs, technical language, etc.).

Complete activities with a real-world context.

Engage in content-driven dialogue.

Reason abstractly.

Reason quantitatively.

Critique the reasonings of others.

Learn about careers related to the instructional content.

Q4.5

Directions: Please respond to the following questions regarding your feelings about learning in general.

“I think it is important that students have learning opportunities to…”
<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree nor disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead others to accomplish a goal.</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Encourage others to do their best.</td>
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<tr>
<td>Produce high quality work.</td>
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<td>Respect the differences of their peers.</td>
<td>○</td>
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<td>Help their peers.</td>
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<tr>
<td>Include others’ perspectives when making decisions.</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Make changes when things do not go as planned.</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Set their own learning goals.</td>
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<td>Manage their time wisely when working on their own.</td>
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<tr>
<td>Choose which assignment out of many needs to be done first.</td>
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<tr>
<td>Work well with students from different backgrounds.</td>
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</tbody>
</table>

Q5.1 Based on your current teaching assignment, how **interested** would you be in participating in professional development about these topics?
<table>
<thead>
<tr>
<th>Issue</th>
<th>Not interested</th>
<th>Possibly interested</th>
<th>Definitely interested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of education technology to support learning</td>
<td></td>
<td></td>
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<tr>
<td>Integrating literacy practices with STEM learning</td>
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<tr>
<td>Formative assessment for STEM learning</td>
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<tr>
<td>Problem-based learning</td>
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<tr>
<td>Interdisciplinary STEM learning</td>
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<tr>
<td>Scientific practices (modeling and argumentation)</td>
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<tr>
<td>Engineering design practices</td>
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<tr>
<td>Mathematical practices</td>
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<tr>
<td>Inquiry–based laboratory activities</td>
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<tr>
<td>Preparing students for achievement tests</td>
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<tr>
<td>Using real-world issues in the classroom</td>
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<tr>
<td>Analysis of “big data”</td>
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<tr>
<td>Supporting classroom discourse</td>
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<td></td>
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<tr>
<td>Science TEKS</td>
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<td></td>
<td></td>
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<tr>
<td>Mathematics TEKS</td>
<td></td>
<td></td>
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<tr>
<td>Instructional strategies for meeting the needs of diverse learners</td>
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<tr>
<td>Aligning instruction and curriculum standards</td>
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<tr>
<td>Strategies for student use of mobile technologies (e.g., iPads, Chromebooks, smart phones)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrating science, technology, engineering, and mathematics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX F

Informed Consent

Baylor University
School of Education

Consent Form for Research

PROTOCOL TITLE: STEM integration in elementary classrooms: A quantitative study exploring impediments and improvements

PRINCIPAL INVESTIGATOR: Erika Neuman

Invitation to be Part of a Research Study

You are invited to be part of a research study. This consent form will help you choose whether or not to participate in the study. Feel free to ask if anything is not clear in this consent form.

Important Information about this Research Study

Things you should know:

- The purpose of the study is to assess the efficacy of educators in STEM content.
- To participate, you must be a certified PK–5 teacher in NEISD.
- If you choose to participate, you will complete an online survey.
- This will take approximately 10–12 minutes.
- There are no known risks to you participating in this study.
- The possible benefits of this study include professional development opportunities that meet your needs and preferred methods.
- Taking part in this research study is voluntary. You do not have to participate, and you can stop at any time.

More detailed information is described later in this form. Please take time to read this entire form and ask questions before deciding whether to participate in this research study.

Why is this study being done?

This study aims to identify elementary teachers’ self-efficacy in STEM content and ways that professional development might address the gaps. We ask you to participate in this
study because you are an elementary teacher with valuable insight into self-efficacy and professional development.

<table>
<thead>
<tr>
<th>What will happen if I take part in this research study?</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you agree to participate in this study, you will be asked to complete an online survey.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Are there any benefits from being in this research study?</th>
</tr>
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<tbody>
<tr>
<td>You might benefit from being in this study because collected data will be used to construct professional learning opportunities for NEISD teachers in the future.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How Will You Protect my Information?</th>
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<tbody>
<tr>
<td>The risk of taking part in this study is the possibility of a loss of confidentiality. Loss of confidentiality included sharing your personal information with someone not on the study team and who was not supposed to see or know about your information. The researcher plans to protect your confidentiality.</td>
</tr>
</tbody>
</table>

Confidentiality will be maintained to the degree permitted by the technology used. Your participation in this study involves risks similar to a person’s everyday use of the Internet, including illegal interception of the data by another party. We will make every effort to keep your records confidential. However, there are times when federal or state law requires the disclosure of your records.

The authorized staff of Baylor University may review the study records for quality control or safety. The results of this study may also be used for teaching, publications, or presentations at professional meetings. If your individual results are discussed, we will protect your identity by using a code number or pseudonym rather than your name or other identifying information.

We will send your study information to research collaborators at Friday Institute of Educational Innovation without specific participant data.

You will not be paid for taking part in this study.

<table>
<thead>
<tr>
<th>Your Participation in this Study is Voluntary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taking part in this study is your choice. You are free not to take part or to withdraw at any time for any reason. No matter what you decide, there will be no penalty or loss of benefit to which you are entitled. If you choose to withdraw from this study, the information that you have already provided will be kept confidential. You cannot withdraw information collected before your withdrawal.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact Information for the Study Team and Questions about the Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you have any questions about this research, you may contact:</td>
</tr>
<tr>
<td>Erika Neuman</td>
</tr>
</tbody>
</table>

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Phone: [redacted information]
Email: [redacted information]

Corina Kaul
Email: [redacted information]

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the following:
Baylor University Institutional Review Board
Office of the Vice Provost for Research

Phone:
Email:

By continuing with the survey, you are providing consent.
Dear Hardworking Teachers,

This is a friendly reminder from a fellow NEISD teacher to please complete the complete STEM & Instructional Practice Survey. This information will contribute to making professional development more meaningful.

The survey won’t take long, and your input is incredibly valuable. The deadline to have your voice be heard is May 6, 2022.

Respectfully,
Erika Neuman
5th grade teacher
Bulverde Creek
APPENDIX H

Scatterplots for T-STEM Variables and Integrated STEM Instruction

Figures H.1, H.2, H.3, and H.4 indicate linearity among variables.

Figure H.1. Scatterplot indicating a linear relationship between STEM instruction score and total STEM professional development.
Figure H.2. Scatterplot indicating a linear relationship between STEM instruction score and mathematics teaching self-efficacy.

Figure H.3. Scatterplot indicating a linear relationship between STEM instruction score and science teaching self-efficacy.
Figure H.4. Scatterplot indicating a linear relationship between STEM instruction score and student technology use.
APPENDIX I

Histogram for T-STEM Variables and Integrated STEM Instruction

Figure I.1. Histogram showing normality of residuals predicting STEM instruction score.
APPENDIX J

P–P Plots for T-STEM Variables and Integrated STEM Instruction

*Figure J.1.* P–P plot of standardized residuals for STEM instruction score indicating linearity of relationships between variables.
APPENDIX K

Scatterplot for Heteroscedasticity of T-STEM Variables and Integrated STEM Instruction

Figure K.1. Scatterplot of residuals predicting STEM instruction shows no overly influential cases and heteroscedasticity.
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