A CASE STUDY INVESTIGATION OF PRACTICES AND BELIEFS OF TEACHERS
AT A STEM-FOCUSED ELEMENTARY SCHOOL

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by

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CERTIFICATION OF APPROVAL

I certify that I have read *A Case Study Investigation of Practices and Beliefs of Teachers at a STEM-Focused Elementary School* by Billy J. Martin and that in my opinion this work meets the criteria for approving a dissertation submitted in partial fulfillment of the requirements for the degree: Doctor of Education in Educational Leadership at San Francisco State University.

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Proponents of STEM education have highlighted the need for increasing STEM skills among students. To address this need, there have been recommendations to create new STEM-focused schools, a majority of which are to be STEM-focused elementary and middle schools. However, STEM school research remains focused on outcomes at the secondary and postsecondary level, with little attention being given to knowing more about the role that elementary education plays in STEM outcomes. Case study design was used to investigate teachers at one STEM-focused elementary school to identify the practices and beliefs reported as important in STEM teaching and learning. Using survey and in-depth interviews, it was found that designation as a STEM-focused school promotes the use of more inquiry-oriented teaching practices and facilitates the use of strategies for developing confidence and competence in STEM among staff and students. The information uncovered in this study could provide leaders of any organization desiring to become a STEM-focused institution information about specific beliefs and practices that have the greatest potential to support changes in teaching.

I certify that the Abstract is a correct representation of the content of this dissertation

Stephanie L. Hinton

Chair, Dissertation Committee

June 9, 2016

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Chapter One: Purpose of the Study

Introduction and Background

Educators, policymakers, and others have consistently raised concerns regarding the quality of science education in American schools. Consistently cited are the lower achievement scores of U.S. students compared to their international counterparts (Epstein & Miller, 2011; National Center for Education Statistics, 2012). Other concerns are the declining number of undergraduates choosing to enter and remain in disciplines related to science, technology, engineering, and mathematics (STEM) and the lack of participation of women and other ethnic groups underrepresented in STEM fields (National Science Foundation, 2013). A primary concern is that students without sufficient STEM knowledge and skills will not be able to compete effectively in an increasingly globalized workforce (ACT, 2014; Claussen & Osborne, 2012; Scott, 2010).

STEM skills will continue to become increasingly more important in the lives of students as STEM concepts become more pervasive and expand to encompass a larger number of professions (ACT, 2014). People with STEM skills at all levels of educational attainment, including those with only a high school diploma, tend to earn higher wages as well as maintain lower rates of unemployment as compared to those who have equal levels of education but lack STEM skills (Carnevale, Smith, & Melton, 2011). Not only do STEM-skilled workers earn more income over the course of their lifetime than do

non-STEM skilled workers, but the income gap between racial and ethnic groups among this occupational category is also smaller (Carnevale et al., 2011). This means those who lack adequate STEM preparation will be denied access to careers in the “fastest-growing and most lucrative occupations of the future” (Scott, 2010, p. 18).

The STEM circuit is described as the system of multiple and varying pathways of courses and experiences, both in and out of school (Museus, Palmer, Davis, & Maramba, 2011) that facilitates the acquisition of STEM-skills and prepares students to participate in twenty-first century jobs and careers (Claussen & Osborne, 2012). The skills acquired through participation in this circuit enables people to problem solve, think logically, evaluate evidence, collaborate globally (Duschl, Schweingruber, & Shouse, 2007), and in general, “improve the human condition” (Marshall, 2010, p. 48).

Problem

To address this concern for increasing STEM skills preparation, the 2010 President’s Council of Advisors on Science and Technology (PCAST) recommended that the United States create 1,000 new STEM-focused schools by 2020, 80% of which should be new STEM-focused elementary and middle schools (PCAST, 2010).

Currently, there are so few elementary schools that explicitly embrace a STEM focus, that claims about their potential are not yet supported with empirical evidence. Absent from the existing STEM research base are studies that evaluate the components and effectiveness of STEM-focused elementary schools (Judson, 2014). At present, there is a

lack of agreement and understanding of the necessary components that make an elementary school successful in STEM teaching and learning (Dickerson, Eckhoff, Stewart, Chappell, & Hathcock, 2013). Additionally, not much is known about how elementary schools successful in STEM teaching and learning are similar to and different from elementary schools without a STEM focus (Hansen, 2014).

Supporters of STEM education have repeatedly expressed the need to identify the critical components of specialized STEM-focused schools that facilitate, moderate, or constrain success in STEM in the hopes of creating learning environments that effectively prepare students in STEM disciplines (Erdogan & Stuessy, 2015; Hansen, 2014; Museus et al., 2011; National Research Council, 2013; Peters-Burton, Lynch, Behrend, & Means, 2014). Still, research has remained narrowly focused on the STEM outcomes at the high school and postsecondary levels (Wells, 2013), with little research being conducted in regard to the role that elementary education plays in STEM outcomes. Educational practices may be among the most useful criteria for determining the efficacy of STEM-focused schools (National Research Council, 2011). Therefore, the objectives of this study were to identify practices and beliefs STEM-focused elementary school teachers report as important for promoting STEM teaching and learning, and to examine how these practices and beliefs compare to those of teachers in the general population.

Disproportionate Participation in STEM

As stakeholders continue to argue for the need to increase the quantity and diversity of students preparing to enter STEM disciplines (Museus et al., 2011), the number of undergraduates choosing to enter and remain in STEM disciplines continues to decline (National Science Foundation, 2013). The higher attrition of Women, African Americans, Hispanics/Latinos, and American Indians/Alaska Natives (National Science Foundation, 2013) is especially concerning as demographic trends suggest that racial and ethnic groups currently considered minorities will soon make up the majority of the U.S. population (Kirsch, Braun, Yamamoto, & Sum, 2007; Museus et al., 2011).

This underrepresentation of certain groups in STEM education is evident in the STEM circuit from early education to the workforce. For example, Black, Latina/o, Native American, and other underrepresented minorities combine to represent approximately 40% of the nation's K-12 student population, yet they earn only 17% of the bachelor's degrees in engineering and natural sciences and less than 7% of the doctorates in those disciplines (Olson & Labov, 2012). Similarly, they make up a smaller share of the STEM workforce than their proportion in the general population. While Hispanics/Latinos, Blacks, and American Indians/Alaskan Natives comprise 26% of the U.S. population ages 20-70, they made up only 9% of the STEM workforce in 2008 (National Science Board, 2010).

However, improving outcomes of underrepresented minorities in STEM disciplines is as much an ethical issue as it is an issue of global competitiveness. Access to and success in STEM courses such as math and science opens doors to more advanced education opportunities (Museus et al., 2011). These improved opportunities will not only increase the likelihood of participation in higher wage careers (Scott, 2010), but will also expand the social opportunities of individuals from these underrepresented groups as well (MacPhee, Farro, & Canetto, 2013).

Researchers have argued that to adequately equip students with these essential STEM skills, STEM-related experiences should begin much sooner than high school. It is suggested that to promote STEM interest, STEM experiences should begin in the elementary grades (Museus et al., 2011). The elementary years have been shown to provide a critical foundation upon which future aspirations, interests, and learning are built (Epstein & Miller, 2011). Floersheim and Johnston (2010) cautioned that high school is far too late to expect any amount of academic excitement to correct previous damage done to students' interest and ability in STEM courses. Thus, examining the role that elementary school plays in influencing STEM interest and engagement among students is a valuable endeavor, particularly important for the potential for strengthening the persistence of those traditionally underrepresented in STEM disciplines.

Research Questions and Design

To begin exploring the role that elementary education plays in facilitating, moderating, or constraining success in STEM, this study will examine the practices, characteristics, and beliefs of teachers at a STEM-focused elementary school by investigating the following research questions:

1. How do preparation, self-efficacy, practice, and beliefs about teaching and learning of teachers at a STEM-focused elementary school compare to a larger representative sample of elementary teachers in California?
2. What instructional practices do teachers at a STEM-focused elementary school report as promoting STEM learning?
3. What supports and resources do teachers at a STEM-focused elementary school identify as critical in developing and promoting STEM teaching and learning?

Studies involving an examination of teacher beliefs have historically been criticized for a lack of contextualized data due in part to an over reliance on single measures of data, most often self-report surveys (Wheatley, 2005). Therefore, this study relied primarily on qualitative data collected through in-depth semi-structured interviews. This methodology supported the gathering of compelling and robust information from teacher participants (Yin, 2014).

Conceptual Framework

The perspective used to frame this study is taken from the *school ecology framework* (Erdogan & Stuessy, 2015) and the *Opportunity Structures for Preparation and Inspiration in STEM* (OSPri) critical components of inclusive STEM-focused high schools (Peters-Burton, Lynch, Behrend, & Means, 2014). Together, these two frameworks provide a lens with which to objectively investigate the practices teachers at a STEM-focused elementary school identify as important in STEM teaching and learning.

School ecology theory (see Figure 1) provides a framework to examine ways in which actors, in this case teachers, within the school setting utilize contextual factors such as beliefs and instructional practices to influence actions meant to improve school experiences and outcomes. Ecology refers to a system of nested relationships among and between individuals and their environment (Weaver-Hightower, 2008). While traditional examinations of education environments may be unable to fully appreciate the complexity of the interrelationships between individuals and their environment (Weaver-Hightower, 2008), studies employing an ecological framework give scrupulous attention to the intricate interactions between individuals and their environment in an effort to appreciate both human behavior and the physical settings in which it transpires (Hamilton, 1983). As a result, schools as ecological systems have been proposed as a framework for how school-wide environmental components contribute to the school experience (Erdogan & Stuessy, 2015; Waters, Cross, & Shaw, 2010). This ecological

framework suggests that particular school experiences are the result of interrelationships between and among various components of the school setting. Components of the school environment are grouped into three categories: actors, contextual factors, and actions.

Actors in ecology framework are those with individual roles (Erdogan & Stuessy, 2015). These include students, staff and faculty, administrators, community leaders, and role models. Students, however, are the principal actors, whereas teachers, administrators, and others are secondary due to their supporting role to students (Erdogan & Stuessy, 2015). Placing students in the role of primary actor in this framework has been done to intentionally promote the use of student-centered learning environments (Erdogan & Stuessy, 2015). While actors are the people within the school ecosystem, the contextual factors are the pedagogical processes at the classroom level.

Contextual factors are, for the most part, intangible classroom elements (Erdogan & Stuessy, 2015). The learning environment serves as the primary contextual factor. What is known and understood about modern learning environments has changed considerably over the past several decades. Contemporary contextual factors include curricula, instructional strategies, technology resources, museums, parks, role models, classroom culture, and the integration of disciplines (Erdogan & Stuessy, 2015). While contextual factors alone do not determine the learning outcomes of students, the effects of these classroom elements are enhanced through the collaborative relationships that develop among the actors.

The last category within the school ecology framework is action. It is proposed that student outcomes are improved by the effect that results from the relationships developed among and between actors within an environment (Erdogan & Stuessy, 2015). These collaborative relationships include mentoring provided to teachers and students, as well as partnerships with members of the community beyond the school. Cooperation among actors is another example of an outcome of collaborative relationships (Erdogan & Stuessy, 2015). Formative assessment used to guide and improve instruction is an additional example of action that results from collaboration. A common thread that runs through all actions is relationships that develop from cooperation meant to support student outcomes.

The second concept underpinning this study is Opportunity Structures for Preparation and Inspiration in STEM (OSPri). The goal of OSPri researchers has been to identify how *inclusive STEM-focused high schools* (ISHSs) function by examining features that are common among several STEM-focused high schools. These researchers defined inclusive STEM-focused schools as secondary schools that do not require students to demonstrate minimum levels of aptitude or interest in STEM for enrollment, self-identify as a STEM school, and are not a newly established institution (Lynch et al., 2013). Researchers at OSPri have conducted cross-case analyses of several inclusive STEM-focused high schools. These case study investigations, along with a review of STEM school research literature, have resulted in a list of ten components that OSPri

have hypothesized as essential for contributing to successful STEM teaching and learning outcomes. The ten potential critical components are summarized in Table 1.

Table 1

Definitions of OSPrI Candidate Critical Components

1. **STEM-focused curriculum.** Courses in all 4 STEM disciplines are offered, or, engineering and technology are integrated into other content areas.
 2. **Reform Instructional Strategies and Project-Based Learning.** Classes emphasize active and authentic instructional practices informed by current research. Students are provided opportunities to engage in project-based learning. Performance-based assessment practices have an authentic fit with curriculum.
 3. **Integrated, Innovative Technology Use.** Students are connected to information, data, research, teachers, and mentors via technology during and outside the school day.
 4. **Blended Formal/Informal Learning beyond the Typical School Day, Week, or Year.** Students are provided learning opportunities that are not strictly connected to the typical classroom.
 5. **Real-World STEM Partnerships.** Students have opportunities to connect and interact with business/industry/world through mentorships, internships, or projects that occur within or outside the traditional school day/year.
 6. **Early College-Level Coursework.** Students can access classes and/or resources at local higher education institutions.
 7. **Well-Prepared STEM Teaching Staff.** Teachers are qualified and have advanced STEM content knowledge either through education or practical experience.
 8. **Inclusive STEM Mission.** School goals are to prepare students for STEM.
-

9. **Administrative Structure.** The administrative structure varies depending on how the school is modeled, converted, or created.

10. **Supports for Underrepresented Students.** Supports are put in place to facilitate the success of underrepresented students.

Reprinted from "Chicago High School for Agricultural Sciences: A case study of an inclusive STEM-focused high school in Chicago, Illinois." by Behrend, et al., 2014, George Washington University: Opportunity Structures for Preparation and Inspiration in STEM.

Because no studies exist that have examined the structures and components of STEM-focused elementary schools, the research perspective for this study had to be guided by research conducted at the high school level. As such, some of the components that have been identified as critical to successful STEM-focused high schools are not relevant at the primary level. For example, early college-level coursework is not relevant for elementary school students. Regardless, OSPri provides an entirely appropriate framework for examining the components and practices within the ecology of a STEM-focused elementary school.

As a conceptual framework, the work of Erdogan and Stuessy, (2015) and OSPri's critical components of STEM-focused high schools (Lynch et al., 2013; Peters-Burton, Lynch, Behrend, & Means, 2014; Peters-Burton, Lynch, House, & Han, 2014) represent two perspectives from which to view the practices and beliefs of the teachers investigated in this study. Erdogan and Stuessy's ecology metaphor provides guidance to examine how the components within the school context work together to influence experience. While OSPri's critical components of successful STEM-focused schools

provide guidance for examining the contextual factors that may be specific to STEM-focused ecologies rather than a focus on all components in general. An illustration of the integration of these two perspectives is included in Figure 1.

Figure 1. Illustration of conceptual framework

Study Significance

There are several valuable reasons to investigate teacher practice related to STEM instruction at the elementary school level. The first is to add to the scant literature base of STEM-focused elementary schools. Very little research explicitly focuses on STEM

initiatives at the elementary level (Epstein & Miller, 2011). Rather than provide insight into effective school design, practices, or essential professional development, the majority of elementary STEM research, instead seems to highlight specific isolated activities related to STEM disciplines and offer detailed procedures for the implementation of these activities in the classroom (Brown, 2012).

In addition, the information found from this study has the potential to provide school systems, administrators, teachers, and community members with insight into the decision-making processes of STEM-focused elementary school teachers. This data then has the potential for identifying and opening opportunities by highlighting influential forces for school improvement issues (Weaver-Hightower, 2008). That is to say, the information uncovered in this study could aid any organization desiring to become a STEM institution with important knowledge for the creation of professional development activities and other supports for actors within the school ecology. Understanding the salient practices of teachers at STEM-focused elementary schools will enable school leaders to highlight specific beliefs and practices that have the greatest potential to support changes in actual teaching (Wheatley, 2005).

Lastly, understanding the role early STEM education plays in stimulating and strengthening STEM-related skills is a moral and ethical imperative. As discussed previously, the economic benefits of improving STEM outcomes has been clearly established. However, increased STEM literacy also leads to a more informed and

effective citizenry. Even those who do not pursue STEM related careers would benefit from increased STEM literacy as STEM skills continue to be increasingly essential for people to make informed decisions about science and technology driven political and social issues (National Research Council, 2011).

Chapter Two: Literature Review

Methodology of Literature Review

This chapter reviews the literature to determine which school environmental factors are influential in the teaching and learning of STEM topics in elementary school classrooms. Specialized schools are increasingly becoming options for parents and students; therefore, the first section provides an overview of the role of specialized STEM schools. The second section presents research related to inquiry-oriented teaching practices found in STEM content areas. Because self-efficacy influences the ways teachers engage students in STEM content, the pedagogy section is followed by an examination of how self-efficacy affects the decision-making processes of teachers. The fourth section presents an analysis about ways in which teachers' develop and strengthen self-efficacy. The last section makes an explicit connection to the conceptual framework of the paper by providing a brief presentation of schools as ecological systems. This section provides a discussion of the various school factors that may further influence teachers' decisions making processes regarding STEM teaching and learning. The literature review concludes with an overall summary of the chapter.

Role of Specialized Schools in STEM Learning

The weaknesses of the STEM pipeline within American public schools have been highly publicized for some time (Epstein & Miller, 2011). While debates rage over precisely which issues are most pressing, there is unanimous agreement that there is room

to improve the academic outcomes of U.S. students in regards to STEM achievement. Despite overall low amounts of time and resources devoted to STEM disciplines in K-12 education, there is a history of specialized schools that emphasize math and science education, and increasingly, the schools are embracing the broader STEM umbrella that includes engineering and technology. In the U.S., these specialized schools take the form of magnet schools, specialized public schools, and charter schools.

Charter schools are defined as tuition free, publicly funded schools that operate outside the traditional restrictions of public schools and attract students from a wide geographical area (Judson, 2014). Specialized schools are public schools that have a particular curricular specialization, for example performing arts, language, or science. These schools enroll students from a local geographical area within specified attendance boundaries. Magnet schools are defined as specialized schools operated by a traditional school district and admitting students from a wide geographical area beyond traditional school boundaries (Goldring & Smrekar, 2000; Judson, 2014).

The term “magnet” gained popularity in the 1970s as a branding campaign by policy makers in an effort to make some schools appear more attractive to parents, students, and the education community (Goldring & Smrekar, 2000). Sometimes referred to as “alternative schools” or “schools of choice” (Dohrmann, Gartner, Lipsky, Kerzner, & Grimm, 2007), these magnet schools had at the heart of their core mission the intention of protecting civil rights through outreach, free transportation for students, and an explicit

goal for desegregation (Frankenberg, Siegel-Hawley & Orfield, 2008). For decades, magnet schools have been a cornerstone of school desegregation efforts (Olson Beal & Hendry, 2012; Ryoo, 2014).

Today, the mission of magnet schools still includes the purpose of racial integration, but has become more focused on establishing a particular academic niche through specialization in an effort to compete with the rising attendance rates of charter schools (Frankenberg et al., 2008). On one hand, contemporary magnet school supporters believe magnet schools can improve academic performance and aspirations of students by offering specialized themes (Bifulco, Cobb, & Bell, 2009). Advocates believe choice will force traditional school systems to become more responsive, efficient, and effective (Cullen, Jacob, & Levitt, 2005). Proponents of school choice programs believe that allowing selection into alternative schools, such as magnet schools, will force schools to compete for students by “improving the quality of the educational product” (Olson Beal & Hendry, 2012, p. 522). On the other hand, critics of magnet schools fear increased choice will further harm disadvantaged children by funneling away resources and more fortunate students (Cullen et al., 2005), essentially leaving disadvantaged students behind in schools then destined to become among the worst performing.

Despite concerns regarding the impact upon those children not attending magnet schools, they appear to be a popular alternative within the public school system. Magnet schools are located in 31 states and enroll nearly twice as many students as charter

schools (Frankenberg et al., 2008), often with a greater demand than available space (Judson, 2014). Furthermore, President Obama demonstrated support of magnet schools during his 2011 Back-to-School speech when he committed to the continuation of magnet school financial support through the Magnet Schools Assistance Program (Judson, 2014).

Although specialized schools are a popular school choice, research about the academic effectiveness of these schools is mixed. For example, in their efforts to measure how transferring to a magnet school from a non-magnet school affects academic outcomes, Bifulco et al. (2009) found that achievement in math and reading is higher among magnet high school students than non-magnet high school students. In another example, Gamoran (1996) used data from the federal National Educational Longitudinal Survey (NELS) to approximate differences in 10th grade achievement for students attending a variety of school types, including magnet schools. He concluded that magnet schools were more successful at raising student success in reading and social studies than public or private schools. However, Judson (2014) later contradicted such findings by reporting that magnet school achievement is no greater than achievement at traditional public schools. While the research of Bifulco et al. (2009), Gamoran (1996), and Judson (2014) focused on magnet high schools, research at the elementary level have also revealed mixed results. For instance, Dohrmann et al. (2007) claimed that the academic outcomes of elementary magnet school students was lower than students from non-magnet schools, even after controlling for ability prior to enrollment. Despite these

conflicting outcomes, Gamoran (1996) alerted magnet school critics, as well as supporters, that “the positive effects of magnet schools need to be taken seriously” (p. 11).

Though agreements on the academic outcomes of magnet schools remain mixed, there appears to be emerging consensus that magnet schools are better able to improve the environmental factors of the school context. For example, several researchers have concluded that magnet schools maintain academic environments that are more positive with higher expectations of students (Gamoran, 1996; Olson Beal & Hendry, 2012). Frankenberg et al. (2008) pointed out that magnet and charter schools enroll a larger share of Black and Latino students than do traditional public schools. Furthermore, magnet schools tend to have learning environments that are less racially and economically isolated than traditional public schools (Bifulco et al., 2009; Olson Beal & Hendry, 2012). Research has also suggested that the diversity effects of magnet schools extend beyond the school campus by alleviating residential segregation (Frankenberg et al., 2008).

More recently, however, schools with STEM themes have emerged as a potential solution to improving interest and retention in STEM disciplines by offering parents and students a more science-rich option to traditional public schools. Although the majority of empirical studies examining specialized STEM schools have relied solely on self-report data provided by high school principals (Brody, 2006), a few researchers have

examined common characteristics among specialized STEM high schools or student outcomes. For example, Tofel-Grehl and Callahan (2014) used observation and interview data to explore beliefs of students, teachers, and administrators at six specialized STEM-focused high schools. Student participants stated that working together with a shared interest, in this case a STEM focus, resulted in learning environments that were more welcoming and inclusive than what they had experienced in more traditional school settings. In another example, Peters-Burton, Lynch, House, and Han (2014) surveyed specialized STEM high school literature and compiled a list of critical components they hypothesized would be necessary for successful STEM outcomes. This list included such things as STEM-focused curriculum, project-based learning environments, technology use, STEM industry partnerships, and teachers prepared in STEM content. Although primarily concentrated at the secondary level, Tofel-Grehl and Callahan (2014) and Peters-Burton et al. (2014) provide a framework for examining characteristics of STEM-focused elementary schools.

Hansen (2014) conducted one of the few studies that examined student outcomes of specialized STEM schools. Results from this study revealed that students had lower achievement in mathematics than did students in a non-STEM school. However, Subotnik, Tai, and Almarode (2010) used survey results to demonstrate that students graduating from STEM schools were more than twice as likely to enter college declaring STEM majors than students from non-STEM schools. Similarly, Thomas and Love

(2002) revealed that more than 50% of interviewed STEM high school graduates intend to major in STEM disciplines in college (Thomas & Love, 2002).

As noted earlier, the majority of published research regarding specialized STEM schools is concentrated at the secondary and post secondary level (Judson, 2014). What does exist regarding STEM at the primary level appears focused on extra curricular programs offered to students that take place afterschool and during summer sessions or studies on professional development targeted at training teachers in STEM content. For example, Whitman and Witherspoon (2003) conducted a teacher-training seminar designed to train teachers to use LEGO robotics equipment to engage students in engineering. These researchers highlighted the extensive amount of time and effort needed for teachers to make the curricular changes necessary to make STEM teaching successful. However, Sikma and Osborne (2014) provide one of the only qualitative examinations of STEM-focused elementary schools. Their work chronicles the process of one elementary school's transformation from a non-STEM school to a specialized STEM-focused elementary school. Teachers in this study admitted that STEM involves many subjects that are new and uncomfortable, such as engineering. Teachers also reported that the lack of a clear STEM school definition caused great confusion.

At present, results for STEM-focused elementary schools do not reveal much. However, STEM-focused elementary schools have been the topic of so few empirical studies that it is unknown how a STEM-focus contributes to important ecological

components like building a community of learners or how such schools might facilitate or constrain student interest and persistence in STEM disciplines.

Inquiry-oriented Teaching Practices in STEM Content Areas

Several groups have responded to concerns regarding the quality of science education in American schools. These groups have responded with recommendations and policy creation meant to reform science education under the assumption that current science education practices are not effective in promoting student learning or interest in STEM subjects (Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011; National Research Council, 1996; National Research Council, 2011). These reformed-based policies highlight an inquiry-centered approach to instruction as opposed to the teacher-centered approach that has dominated classroom instruction in the past (Duschl et al., 2007; National Research Council, 2011).

In order to more clearly understand this reformed approach to teaching, it is important to identify what is meant by the term “inquiry,” as inquiry is at the heart of the reform effort. The National Science Education Standards (National Research Council, 1996) refer to inquiry as activities that promote knowledge and understanding of ideas and the natural world. Others describe inquiry as an approach to teaching and learning that is guided as minimally as possible by content experts or teachers (Kirschner, Sweller, & Clark, 2006). While it is difficult to find a precise definition of inquiry in the research literature, in general inquiry refers to a continuum of student engagement in investigation

and problem solving. At one end of this spectrum is open-ended inquiry where students generate and carry out their own investigations, while at the other end is teacher-centered inquiry, where the teacher selects the content to be investigated (Blanchard et al., 2010; National Research Council, 2000)

Blanchard et al. (2010) has described this continuum as levels of inquiry. Inquiry levels range from 0 to 3. Level 0 has the least amount of student responsibility, while level 3 has the most. In Level 0 inquiry or verification, the teacher is responsible for posing the guiding questions, providing the data collection methods, and for offering students the interpretation of the results. Level 1, the structured level, the teacher provides the question and data collection methods, but allows students to interpret results. In level 2, or guided inquiry, the teacher provides the investigative questions, while students collect the data and interpret results. In reaching level 3, or open inquiry, students become responsible for all parts of an investigation, including determining what is to be examined. Regardless of the inquiry level being employed, it is important to understand that in inquiry-based instruction, students engage in some manner the process of generating knowledge, such as asking questions, hypothesizing, and/or generating, interpreting, and evaluating data (Duschl et al., 2007; National Research Council, 2000). During this type of instruction, teachers guide students to generate their own knowledge through science-based practices, rather than simply transmitting facts to students through lecture or reading (Duschl et al., 2007).

Although measuring the impact of reformed teaching practices on students has been a challenge, evidence suggests that reformed teaching does have a positive effect on student learning (Colburn, 2006). Sawada and Pilburn (2000), for example, created the Reformed Teaching Observation Protocol (RTOP) in order to measure the level of reform in mathematics and science classrooms. The RTOP utilizes a definition of reform built from an extensive review of the literature regarding science and mathematics teaching reform. Using this instrument, Sawada, Turley, Falconer, Benford, and Bloom (2002) found that when teaching is aligned with reform recommendations, student achievement increases.

More recently, Geier et al. (2007) attempted to add additional empirical evidence to the inquiry-based instruction discussion by testing whether an active-learning curriculum is more effective than a traditional, teacher-oriented curriculum. The study followed approximately 5,000 students and 37 teachers in 18 schools over 3 years. The results showed that students who participated in the active-learning curriculum significantly outperformed those students in traditional oriented curriculum on state standardized tests (Geier et al., 2007). Furthermore, for each year students engaged in inquiry-based instruction, results increased, and the effects were long lasting as demonstrated a year and a half post instruction (Wilson, Taylor, Kowalski, & Carlson, 2010). These demonstrated results were both cumulative and enduring. Hmelo-Silver, Duncan, and Chinn (2007) conclude: “there is growing evidence from large-scale

experimental and quasi-experimental studies demonstrating that inquiry-based instruction results in significant learning gains in comparison to traditional instruction,” (p. 104).

Despite the positive effects of inquiry-based teaching and learning, the topic is not without criticism and confusion. Researchers in the education community have published many reports about the effectiveness of inquiry-based instruction that include definitive, inconclusive, and even negative results (Colburn, 2006). One such article challenging the effectiveness of inquiry-based instruction comes from Kirschner et al. (2006). These researchers assert that empirical evidence gathered over the past fifty years from a small number of studies has indisputably proven that minimally guided instruction is less effective and less efficient than traditional teacher-guided instruction. They further argue that learners know how to construct knowledge only when given adequate and accurate information, and that, with partial information, students risk developing incorrect representations.

Several proponents of inquiry-based instruction have further criticized the research field for a lack of empirical studies that examine the outcomes of reform-based instructional practices among diverse populations (Geier et al., 2007; Lee & Luykx, 2005). Among the few studies examining the effects of inquiry-based interventions on students from linguistically and culturally diverse backgrounds, Cuevas, Lee, Hart, and Deaktor (2005) worked with third and fourth grade students from six elementary schools in a large, urban school district. Their study suggested that regardless of gender, age,

grade, ethnicity, or English proficiency, students who participated in inquiry-based instruction improved their ability to solve problems and formulate conclusions (Cuevas et al., 2005).

The recently adopted *Next Generation Science Standards* (NGSS) demands the use of more inquiry-oriented teaching strategies. This change in standards has led to an increase in the number of teacher preparation programs that apply the standards recommended in reform documents to the education of new teachers of science.

However, many of the recommended reform teaching strategies are not regularly applied by practicing K-12 teachers to their own science instruction. This is especially true in elementary classrooms where teachers often do not have extensive backgrounds in science content or science instruction, causing them to fall back on the teacher-centered, fact-based traditional ways that they experienced instruction in science classes (National Research Council, 2011). In addition, due to social and political constraints promoting reading, writing, and mathematics, it is not difficult for many K-6 teachers to almost avoid science instruction completely (Dorph et al., 2011; National Research Council, 2011). Consequently, in much of the United States, science instruction continues to be poor, limited, or nonexistent at the elementary school level (Banilower et al., 2013; Dorph et al., 2011; Judson, 2013).

Teacher Efficacy Beliefs

If it is expected that positive changes are made in the ways that STEM content is taught at the elementary level, we must understand why teachers use the instructional strategies they do or what elements influence teacher behaviors and decision making processes. That is, if we want teachers to apply inquiry-based teaching strategies to their classroom lessons as recommended by Duschl et al. (2007), National Research Council (2000), and others, we need to understand what causes teachers to implement, or not implement, such strategies.

Many factors influence the behavior of teachers, such as knowledge, beliefs, attitudes, experience, support, and emotions (Hoy & Spero, 2005; Palmer, 2011; Tschannen-Moran & Hoy, 2007). Research implies that beliefs have a particularly strong influence on teacher actions, since “the beliefs teachers hold influence their perceptions and judgments, which, in turn, affect their behavior in the classroom” (Pajares, 1992, p. 307). In some contexts, beliefs may be a stronger predictor of teacher practice than knowledge (Pajares, 1992), therefore, it is important to understand which beliefs or sets of beliefs influence teachers’ decisions to implement reform-based strategies in the classroom.

It is recognized in the research literature that defining beliefs is “a daunting undertaking” (Pajares, 1992, p. 309). This challenge is partly fueled by the interchangeable use of the terms “belief” and “knowledge” throughout education

research. Pajares (1992) suggests that to alleviate this challenge, researchers should operationalize “beliefs” to establish a clear definition of the term. For the purposes of this study, a belief is defined as a concept that an individual accepts to be true regardless of the level of accuracy beyond the holder of the belief (Lester, 2007). In other words, individual beliefs do not need to be agreed upon as valid, correct, or appropriate by others.

Beliefs have been shown to be an important part of the foundation upon which science teacher behavior is based (Mansour, 2010). Several studies have demonstrated how teacher beliefs may influence teacher decisions regarding science instruction. For example, Cronin-Jones (1991) identified four categories of teacher beliefs that influenced implementation decisions of teachers: beliefs about how students learn, beliefs about teacher’s role in the classroom, beliefs regarding the ability levels of students, and beliefs about the importance of topics.

Teacher efficacy beliefs, the extent to which teachers believe they can influence student learning through their teaching behaviors, was first introduced by the RAND Corporation in the 1970’s (Dembo & Gibson, 1985). Later, Bandura (1977) described self-efficacy as the belief in one’s ability to “successfully execute the behavior required to produce outcomes” (p. 193). Similarly, Kagan (1992) defined teacher self-efficacy as the belief teachers maintain in their capability to execute actions that will result in successful completion of specific teaching tasks.

It has been hypothesized that beliefs influence the quality of decisions teachers make about classroom practice because the strength of an individual's belief in their effectiveness is likely to determine whether or not the person will even try to handle a given situation (Bandura, 1977). For example, teachers with high levels of self-efficacy may be more willing to experiment with new practices and techniques (Vartuli, 2005), handle classroom interruptions more flexibly, and engage students more effectively (Gibson & Dembo, 1984). On the other hand, teachers with low levels of self-efficacy may resort to superficially covering academic topics while maintaining a stronger focus on classroom control (Vartuli, 2005). Increased self-efficacy may also increase the likelihood of using more democratic teaching methods such as cooperative learning, small-group activities, and problem-based learning strategies (Ross, 1995). Ross (1995) further suggested that those with higher self-efficacy may have increased goal attainment, greater responsibility for failures, and fewer negative thoughts that may lower performance. Additionally, self-efficacy and confidence have also proven to be relatively robust indicators of how teachers will respond to unfamiliar or adverse situations, possibly even more so than past performance (Bandura, 1977).

Although self-efficacy refers to the level of confidence teachers maintain regarding how capable they feel to teach specific material (Rubie-Davies, 2012; Wheatley, 2002), it has been noted that self-efficacy beliefs may be subject-specific and not held equally across all content areas (Wheatley, 2002). Research has also suggested

that teachers who believe they have a well-developed conceptual understanding of the content they teach tend to provide explanations and examples that are more conceptual in nature and that they are more likely to modify resources to meet the needs of students (Kagan, 1992). This may be contrasted with teachers who maintain a more superficial understanding of subjects they teach and tend to rely more heavily on prepared curriculum and do little to modify resources regardless of student needs (Kagan, 1992).

It is widely reported that content-specific beliefs held by teachers impact the instructional decisions they make. For example, observational data suggests that teachers with high self-efficacy dedicate more time to academic activities, while those with low self-efficacy tend to devote more time to nonacademic tasks (Gibson & Dembo, 1984). However, researchers seem unable to agree as to the degree to which beliefs actually influence the decisions teachers make about instruction. Some researchers assert that teacher beliefs play a pervasive role in the kinds of classroom instruction chosen (Kagan, 1992). For example, it is reported that teachers who hold more traditional beliefs such as good grades or speed as measures of math ability tend to allow students less autonomy and create classroom contexts in which mistakes should be avoided (Stipek, Givvin, Salmon, & MacGyvers, 2001). On the other hand, teachers who are more confident appear to be more willing to implement new and innovative practices than their less confident peers (Rubie-Davies, 2012). Additionally, it has been noted that teachers solve classroom problems largely by relying on their own beliefs (Kagan, 1992).

Even though self-efficacy has been heralded as one of the key motivation factors that influence teacher decisions and student outcomes (Klassen, Tze, Betts, & Gordon, 2011), the research in the field of teacher beliefs has also been criticized for its shortcomings. Among these criticisms are accusations that teachers may claim to be more confident than they actually are (Wheatley, 2005). Some acknowledge that the current empirical evidence surrounding teacher beliefs does not support the existence of a convincing relationship between teacher beliefs and actual practices (Wen, Elicker, & McMullen, 2011). Opponents claim that there is a lack of longitudinal and qualitative data limiting understanding of how teacher efficacy is formed (Klassen et al., 2011; Wheatley, 2002). Wheatley (2005) further notes that there is an overreliance of teacher efficacy data drawn from self-report surveys that are absent of subject matter context and tend to pose vague questions that lead to inconsistent interpretations, raising questions regarding reliability and validity (Tschannen-Moran & Hoy, 2001).

Sources of Teacher Self-Efficacy Development

Much of the research regarding the development of teacher self-efficacy has been rooted in the four sources of self-efficacy proposed by Bandura (1997): mastery experiences, vicarious experiences, verbal persuasion, and physiological or emotional state. The most powerful of these pathways is mastery experiences (Tschannen-Moran, Hoy, & Hoy, 1998). Mastery experiences come from actual participation in an activity (Tschannen-Moran & Hoy, 2007). If activities are determined successful, confidence and

efficacy may improve (Yuruk, 2011). Conversely, if the activity is met with disappointment or failure, efficacy and confidence are diminished. Cantrell, Young, and Moore (2003) found that preservice student teachers who participated in methods courses where practicum teaching experiences were required demonstrated significantly higher self-efficacy scores related to science teaching than those students who did not actively practice teaching lessons. Similarly, Yuruk (2011) reported that increased participation in college level science courses leads to increased self-efficacy toward teaching science. Furthermore, the efficacy changes from mastery experiences are often enduring (Usher & Pajares, 2008). Additionally, mastery experiences as professional development have been shown to influence teacher self-efficacy. Take for example the recent study conducted by Nadelson et al. (2013) involving 33 elementary teachers from six elementary schools. Here, researchers examined the changes in self-efficacy after a 3-day STEM training. This study reported that participation in the training had a significant positive influence on the efficacy, confidence, and attitude of elementary teachers toward teaching engineering to elementary school students (Nadleson et al., 2013).

Vicarious experiences are those in which there is observation of someone else modeling a particular activity (Tschannen-Moran & Hoy, 2007). Bandura (1997) speculates that vicarious experiences may alter self-efficacy through “transmission of competencies and comparison with the attainments of others” (p. 79). Studies have

highlighted the positive effects that observing confident and skilled science teachers have on the personal self-efficacy toward science of elementary teachers (Palmer, 2011). For example, in-service teachers claimed that observation of classroom practices deemed successful strengthened science self-efficacy (Palmer, 2001). Researchers have also suggested that relationships with mentors and tutors may be sources of vicarious experiences that have the potential to influence changes in teacher self-efficacy (Appleton, 2008; Palmer, 2011). Appleton (2008) provided evidence that in situations where a teacher has decreased self-efficacy, mentors and tutors may be able to provide support and guidance until confidence is increased.

The persuasion received from others is the third pathway for influencing self-efficacy. Persuasion has to do with written or verbal interactions received regarding performance from important participants within the education context, such as administrators, colleagues, parents, and members of the community (Palmer, 2006; Tschannen-Moran & Hoy, 2007). While it is suggested that this pathway influences self-efficacy to a much smaller degree than other pathways, persuasion may affect career and new teachers differently. For example, in a study involving 255 new and experienced teachers, Tschannen-Moran and Hoy (2007) reported that verbal persuasion from site administrators had no effect on the self-efficacy beliefs of novice or experienced teachers. However, written and verbal feedback from colleagues showed potential to

influence the self-efficacy of novice teachers, while the same construct appeared not to affect the self-efficacy levels of experienced teachers.

The final pathway is a person's physical or emotional state. Increased efficacy is related to positive emotions (Cantrell, Young, & Moore, 2003), while decreased efficacy is tied to negative emotions such as anxiety. In a study examining contributing factors of anxiety toward science, 82 in-service elementary school teachers were surveyed. The results of this study suggested that the degree of satisfaction derived from experiences in science influences self-efficacy of teaching science (Yuruk, 2011). In other words, teachers feel less anxious about teaching science with each positive science experience.

Schools as Ecological Systems

School ecology theory provides part of the conceptual framework for this study. This framework offers an approach to examine ways in which actors within the school setting utilize contextual factors to influence actions meant to improve school experiences and outcomes. While traditional examinations of education environments may be unable to fully appreciate the complexity of the interrelationships between individuals and their environment (Weaver-Hightower, 2008), studies employing an ecological framework give scrupulous attention to the intricate interactions between individuals and their environment in an effort to appreciate both human behavior and the physical settings in which it occurs (Hamilton, 1983). Scholars have applied ecology metaphors to education topics as diverse as bullying (Espelage & Swearer, 2004); school

connectedness (Waters et al., 2009); parental involvement (Comer & Haynes, 1991); social-emotional and behavioral development (Eccles & Roeser, 2009); and intervention (Greenwood & Kim, 2012). Though research investigating the ways in which school ecological factors interact to influence achievement outcomes is still evolving (Waters et al., 2010; Thapa, Cohen, Guffey, & Higgins-D'Alessandro, 2013), there is a growing body of research suggesting that school ecology may influence some aspects of STEM interest (Legewie & DiPrete, 2014).

Urie Bronfenbrenner (1976) was the first to propose human development as an ecological system. Several researchers have since expanded this proposal to educational settings. For example, Moos (1979) generalized Bronfenbrenner's ecological model to education contexts and hypothesized that both environmental and personal components of school settings shape academic and health outcomes. Eccles and Roeser (1999) went on to suggest that due to the constant interaction among and between the various levels of the school organization, schools must be considered a system. Waters et al. (2010) proposed a school ecology model that integrates previous school environment research to provide a more holistic representation of the whole-school context by considering the interrelationships of living (students and staff) and non-living (organizational structures) aspects of the school setting. Marshall (2010) stated that teaching and learning environments are "bioresonant," (p. 53), suggesting that school environments not only model the complexities of living systems, but also consider the interrelationship between

participants. He specifically addressed learning environments in STEM magnet schools by describing them as “learning and innovating ecosystems” (Marshall, 2010, p. 53). More recently, Erdogan and Stuessy (2015) further extended the ecology framework to address the specific environmental structures of STEM magnet high schools.

This most recent construct of school ecology organizes components of specialized STEM school environments into three categories: actors, contextual factors, and actions (Erdogan & Stuessy, 2015). Actors of a school ecosystem are those people who perform individual roles (Erdogan & Stuessy, 2015; Weaver-Hightower, 2008). Contextual factors refer to the mostly intangible processes used within the classroom by teachers to affect student achievement (Erdogan & Stuessy, 2015). The collaborative relationships that develop from the interaction of actors within the school ecosystem represent action.

Recent evidence suggests that components of the school environment may serve as catalysts to promote change in the academic identities of at risk youth (Brown, Kanny, & Johnson, 2013). For example, in their study examining educational improvement opportunities for high-risk students, Brown et al. (2013) found evidence that suggested the collective ecology of the school setting acts together to create change. Participants highlighted the overall culture of the school, as well as teacher-student relationships and classroom learning environments as components of the school ecology that contributed to changes to their sense of academic potential.

Legewie and DiPrete (2014) used existing data from the National Education Longitudinal Study (NELS) and the High School Effectiveness Study (HSES) to identify components of the school context that influence the STEM interest of female students. Their research found that schools that provided a more supportive environment resulted in an increase in the proportion of women interested in STEM fields (Legewie & DiPrete, 2014). Furthermore, these researchers found evidence to suggest that the strength of a schools' math and science curricula had a direct relationship on girls' intention to pursue a STEM field, while schools that had gender segregated extracurricular activities sparked less interest. These findings corroborated Bronfenbrenner's (1976) early assumption that events in one aspect of the school setting have the potential to influence outcomes in another area.

School ecology theory has been offered as a rationale for how to improve the school experience and strengthen outcomes by more thoroughly understanding the interaction among components within the school environment (Bronfenbrenner, 1976; Eccles & Roeser, 2009; Moos, 1979; Waters et al., 2009; Weaver-Hightower, 2008). Aside from students, teachers are among the most important actors within the school ecology framework. However, missing from STEM school literature are studies examining the influence a STEM emphasis has on the pedagogical decisions teachers make at the classroom level.

Literature Review Summary

This chapter has provided an overview of research literature regarding school contextual factors that influence teachers' pedagogical decision making processes as they implement strategies for teaching and learning STEM content. While there is a significant body of research regarding teaching self-efficacy and reform-based instructional practices has already been conducted, this review highlights the need for more about specific analysis of factors at the elementary school level that influence STEM teaching and learning. While research has been conducted examining contexts of STEM-focused high schools, little is known about the characteristics of STEM-focused elementary schools. Factors that highlight the need for the proposed study include:

- Specialized schools have existed for several decades and although student outcomes results are mixed, they are a popular choice among students and parents and appear to provide students with a more ethnically and socioeconomically diverse learning environment.
- Specialized schools have emerged as a potential solution to increasing interest and retention while improving outcomes for students in STEM disciplines.
- The majority of data regarding STEM-focused schools is dedicated to the secondary level, with little research examining characteristics of STEM-focused elementary schools.
- The majority of research regarding STEM at the elementary level has focused on

extra curricular programs that take place afterschool and during summer sessions or professional development targeted at training teachers in STEM content.

- Inquiry-based teaching practices are at the heart of teaching reform efforts to improve student outcomes and are described as a continuum of student engagement in investigation and problem solving.
- While it has been suggested that beliefs, particularly content-specific beliefs, influence the quality of decisions teachers make about classroom practice, much of the research has examined the extent to which particular interventions (e.g. methods courses or professional development programs) can increase self-efficacy, as opposed to the direct link between self-efficacy and teaching practice.
- Increased self-efficacy arises from four sources that include mastery experiences, vicarious experiences, verbal persuasion, and physiological or emotional state.
- School settings as an ecological system has been offered as a rationale for how to improve the school experience and strengthen outcomes by better understanding how the various components of the school setting interact.
- Although there exist a very small number of studies that examine STEM-focused high schools through the ecology metaphor, no STEM-focused elementary schools have been so examined.

These key ideas and gaps in the literature set the stage for the research presented in this study by demonstrating a critical need for further research examining the characteristics that may be specific to STEM-focused elementary school settings.

Chapter Three: Methodology

This chapter describes the methodology used to conduct a qualitative case study that examined the practices and beliefs of teachers at one STEM-focused elementary school. It provides details of the site and participant selection. It also provides a description of the data collection and analysis methods used to investigate the research questions.

Purpose and Guiding Questions

The purpose of this study was to begin to explore the role that elementary education plays in facilitating, moderating, or constraining success in STEM outcomes by examining the practices, characteristics, and beliefs of teachers at one STEM-focused elementary school. The research questions guiding this study were:

1. How do preparation, self-efficacy, practice, and beliefs about teaching and learning of teachers at a STEM-focused elementary school compare to a larger representative sample of elementary teachers in California?
2. What instructional practices do teachers at a STEM-focused elementary school report as promoting STEM learning?
3. What supports and resources do teachers at a STEM-focused elementary school identify as critical in developing and promoting STEM teaching and learning?

Design

Studies that have involved an examination of teacher beliefs have been criticized for a lack of contextualized data due in part to an over reliance on single measures of data, most often self-report surveys (Wheatley, 2005). Therefore, a case study design was selected for this study. Several research design experts have suggested the use of case study methods to examine contemporary topics such as STEM-focused elementary schools (Cohen, Manion, & Morrison, 2011; Fraenkel, Wallen, & Hyun, 2015; Yin, 2014). Yin (2014) advocates for case study design due to the potential for uncovering compelling and robust information about real-world situations (Yin, 2014). However, more importantly, case study design allowed for interviews of the persons involved in the events under investigation (Cohen et al., 2011).

The research design involved two stages of data collection among teachers at a STEM-focused elementary school. The first stage used a survey to gather whole school data about teaching practices. The second stage used semi-structured interviews to examine specific teachers' beliefs and practices in more depth.

Role of Researcher

As is characteristic of qualitative research, I, the researcher, was the primary instrument for data collection and analysis (Merriam, 2002). My dual role as an elementary school teacher and an outside researcher provided camaraderie and legitimacy

that established a level of mutual trust and respect that allowed participants to speak openly and candidly.

Several strategies were incorporated in my research methodology to counter any researcher bias. First, an interview protocol was used to increase the consistency of data collection. Reflective journaling was used to collect emerging themes and reflections about data collection. Journal entries occurred at the conclusion of each interview and then often throughout the data collection and analysis process. Critical colleagues helped ensure the accuracy of descriptions and interpretations by challenging my inferences.

Site Selection

Currently there exist no criteria for designation as a STEM-focused school. Neither the U.S. Department of Education nor the California Department of Education outline any specific curriculum or minimum requirements to be labeled a STEM school (Tofel-Grehl & Callahan, 2014). It appears that to be a STEM-focused school, one simply declares itself a STEM school. Although the number of self-selected STEM-focused elementary schools is increasing, they are by no means as abundant as secondary STEM-focused schools (PCAST, 2010). Therefore, with the limited availability of STEM-focused elementary schools in mind, schools considered for participation in this study were intentionally selected (Cohen et al., 2011) from schools identified by the researcher as STEM-focused elementary schools.

To begin the selection process, I conducted a comprehensive Internet search for self-identified STEM-focused elementary schools in California. I examined databases of school names for the words science, technology, engineering, mathematics, or STEM (National Research Council, 2013). This initial search returned several lists of schools that included elementary schools and middle schools. Middle schools were eliminated from this list.

The second determinate of STEM status was a stated STEM emphasis printed in school publicity materials. These materials included such things as school websites and mission statements. I examined available publicity materials and excluded schools that did not clearly state or articulate a STEM emphasis. Application of this criteria narrowed potential school sites down to 16 possibilities.

The third determinate for consideration in this study was the school's admission policy. Because this study intentionally examined public STEM-focused schools, the admission policy had to be inclusive, meaning the only requirement for acceptance was students had to reside within school boundaries. The school could use a lottery system to fill vacancies if more students wished to enroll than there were spots available. However, private schools and academies were not included in consideration for this study as these institutions have the option of being selective with their admission processes. School websites were examined to determine admission policy. Where website resources did not

provide adequate information regarding admission, the school was contacted by telephone to inquire about admission policy. This resulted in five potential school sites remaining for consideration.

The fourth determinate of STEM status was instructional time dedicated to a STEM discipline other than mathematics. Although mathematics is considered a STEM topic, all elementary schools, even those without a STEM designation, maintain a curricular focus on mathematics. While there is no “right amount” of science (Dorph et al., 2011), a STEM-focused school devotes more than the 30-minute weekly session that is characteristic in non-STEM elementary schools (National Research Council, 2013). For inclusion in this study, schools must provide at least 60 weekly instructional minutes in science, technology, and/or engineering for all students, as reported by the school site principal. The principals of each of the remaining potential school sites were contacted via telephone. Four site principals confirmed the number of science instructional minutes they believed were taught in classrooms.

The final determinate for being a STEM school was the duration of the school’s STEM emphasis. To be considered a STEM-focused school for this study, a school must have had a STEM emphasis for at least the past three consecutive years. This construct established an enduring commitment to STEM initiatives. Again, this determinate was verified by telephone with the school site principal of the four remaining schools. Three of the possible school sites confirmed a STEM focus for the past three or more years.

Of the remaining three possible school sites, one was eliminated due to the site principal's reluctance to reply to email and telephone requests to discuss the purpose of the study. A second school was eliminated after the site principal revealed that the school would be experiencing a large turn over of teachers. Additionally, the site principal would be retiring mid-year and the district had recently appointed a new superintendent. The remaining school that fit all my established criteria for consideration was Madison Elementary School (pseudonym).

Context

Madison Elementary School (pseudonym) is a public K-6 elementary school located in a Northern California suburban neighborhood. It is situated among single-family homes with easy access to shopping and freeways. Some time after opening in 1959, Madison began to experience declining enrollment as the local neighborhood continued to age. In response to the pending closure, Madison staff opted to become a science and math magnet school. These efforts, however, did little to increase enrollment. Moreover, those families who did choose to enroll their children in Madison began to express disappointment in the actual amount, type, and quality of science instruction being provided to their children. In addition, the school was plagued with several principal turnovers, as well as deteriorating student performance. After more than a decade of struggling with shrinking enrollment, declining student performance, and

failure to deliver on its math and science promise, Madison was once again considered for closure in the early 2000s.

The last of a myriad of principals was brought in to oversee the closure of the school. Upon arrival, however, this new principal discovered that neither the community, nor parents, nor the teachers wanted the school closed. Instead, these stakeholders wanted the school to deliver on its promise of an education steeped in science and math.

Today Madison exists as the school district's only magnet school. It is in its fourth year of STEM self-designation, expanding curriculum to include not only math and science but engineering and technology as well. Although the school recently concluded the construction of two new science labs, the majority of the facilities are original construction. The faculty consists of 24 full-time classroom teachers, one full-time computer lab teacher, and one full-time and one-half time science specialist/science lab instructor. In addition to technology use in the classroom, each student receives weekly instruction in computer programming using Programming for Kids curriculum. Students in grades four, five, and six participate in two 50-minute science labs per week, facilitated by the school's science specialist/lab instructor. Students in grades one, two, and three receive one 50-minute science lab per week, while students in kindergarten receive three formal lab sessions per school year. Partnership with a community-based science-curriculum organization allows for a science docent parent volunteer program that provides an additional 6 science labs and support of a yearlong grade level project

for each classroom. Students in grades two, three, and four use and maintain an outdoor garden as additional lab space to compost, raise butterflies, classify bugs, measure plant growth, and other activities.

Because enrollment is open to any student within the school district, it welcomes over 600 economically and ethnically diverse students in grades kindergarten through six from across school site boundaries. A comparison of student enrollment by various characteristics is represented in Table 2.

Table 2: Student enrollment characteristics

Group	Enrollment
Number of students	625
Black/African American	2.1%
American Indian/Alaska Native	0.5%
Asian	42.6%
Filipino	4.6%
Hispanic or Latino	17%
Pacific Islander	0.8%
White (not Hispanic)	26.7%
Two or more races	5.4%
Socioeconomically disadvantaged	14.2%
English Learners	21.1%

Participant Selection

All school site teachers and curriculum specialists were invited to participate in the survey portion of the research project. Invitations to participate were made through email and in-person meetings during site visits. In total, 24 staff members were invited to participate in the survey. I received responses from two teachers stating they were unable to participate at this time. However, 14 teachers participated in the survey, a 58% participation rate.

The primary source of data was in-depth interviews and classroom observations of purposefully selected teachers. Identification of these key teacher participants came from informal suggestions by teachers and the school site principal. Selecting study participants in this manner increased the number of respondents ideally suited for this particular study (Fraenkel et al., 2015), it also increased trust and openness between participant and researcher, therefore provided more meaningful interviews (Small, 2009). Once a teacher was suggested, I sent an email that asked if he or she would be willing to participate in one-on-one interviews about their teaching practices and beliefs (Appendix A).

Ethical Considerations

Several measures were taken to protect the rights of study participants. First, the goals and objectives of the research were presented and discussed with each participant. All participants signed and were given a Letter of Informed Consent (Appendix B). All

written research data were stored in a locked cabinet/desk in a secure location to which only the researcher had access. All electronic data were stored in a device with full disk encryption and password-protection to which only the researcher had access.

Additionally, names and other identifying information were changed to pseudonyms or omitted in the study.

Data Collection

Gaining Access

In summer 2015, I contacted Madison Elementary School's principal via email to introduce the purpose of the study and request an in person meeting to further explain study goals (Appendix C). The site principal agreed to meet at the school site office at the beginning of the school year. During this initial meeting, the details of the study were discussed at length and the principal offered a tour of the campus with opportunities to meet and greet school staff members. At the conclusion of this meeting, the principal agreed to participate in the study and offered support in obtaining permission from the school district superintendent.

Once the school district and San Francisco State University's Institutional Review Board approved permission, the site principal invited me to attend a staff meeting to be introduced to the school faculty and begin the process of recruitment. At this staff meeting, I presented my research study and informed the staff that all teachers were encouraged to participate in the survey portion of the project. Shortly after the staff

meeting, I emailed a link to participate in the survey to all site teachers. Survey participants were offered a \$25 Amazon gift card for participation. Twenty-four teachers were invited to participate and 14 responded, a 58% participation rate.

Phase I: Survey

The purpose of the survey was to learn about the quantity and quality of science instruction in classrooms at the participating school site, as well as teachers' attitudes toward and preparation for teaching science (Dorph et al., 2011). The primary instrument for gathering this data was the Statewide Science Education Survey for Elementary School Teachers (Appendix D). The survey was administered anonymously and included items of different formats: multiple choice, selection of one option or all that apply, dichotomous choices such as "yes" or "no," Likert-scale, and open-ended questions. The survey instrument was previously developed and validated by researchers at the Lawrence Hall of Science and University of California, Berkeley (Dorph et al., 2011).

The survey asked questions related to opinions of science in schools. It included identifying when science should begin being taught in school and how important it is for public schools to provide students education in various content areas. The second section was about the teaching of science. Questions in this section asked the kinds of instructional strategies used to teach science and how often and for how much time science is taught. The third section inquired about the availability of science specialists, while the fourth section asked participants about the kinds of resources offered by the

school or district. The fifth section included questions regarding preparedness to teach science in elementary school. The sixth section asked participants to identify barriers and supports for science instruction in the classroom.

The survey instrument was web-based and all teachers at participating school site were invited to complete. Distributing the survey instrument through a web-based method allowed responses to be automatically stored in a database, making analysis much easier. An informed consent form was posted as the introduction to the survey. Participants had to select an “I agree to complete this survey” type response to begin the survey. This served as consent to participate in this part of the study.

Phase II: Semi-Structured Interviews

The second phase involved information collected from interviews and classroom observations of purposively selected teachers. This information was collected using a semi-structured in-depth interview protocol (Appendix E). The protocol was developed by the researcher through adaptation of interview protocols from previously accepted research on STEM-focused high schools. The interview protocol examined four characteristics of teachers at a STEM-focused elementary school: beliefs, preparation, practices, and support. Interviews began by examining teacher beliefs about STEM teaching and learning. Then teachers discussed activities they had previously engaged in that they believed had prepared them for teaching STEM concepts. Next was an examination of teaching practices. The interview ended with teachers sharing the school-

wide practices and procedures they believed supported or hindered STEM teaching and learning. These in-depth interviews lasted between 52 and 127 minutes and were scheduled at a location and time convenient to the participating teachers.

Validity

Internal Validity

Because no one source of data collection method is infallible (Erickson, 1986), data were gathered through multiple sources that included in-depth interviews and surveys. This methodological corroboration aided in the validity of the data collected (Cohen et al., 2011; Yin, 2014). Another strategy used was critical colleagues. Critical colleagues were used throughout data collection and analysis and provided feedback regarding evolving assumptions (Fraenkel et al., 2015). Comments and recommendations for changes were assimilated into the analysis as the study progressed.

External Validity

Providing a rich account of the research setting strengthened the external validity for this study. This included providing thick descriptions of the study participants to aid readers in determining the potential transferability of the findings (Cohen et al., 2011; Creswell & Miller, 2010). Such descriptions were meant to provide details such that readers could vicariously experience phenomena and determine for themselves to what extent the situation can apply to his or her own context (Merriam, 2009).

Data Analysis Procedures

The data gathered from the survey were used to identify STEM-focused elementary school teachers' opportunities for professional development and characteristics regarding beliefs and perceptions of preparedness. These data were used to compare to a larger representative sample of elementary teachers in California to gather a sense of the ways teachers at a STEM-focused elementary school are the same as or different than other elementary school teachers in California.

The qualitative data collected from interviews and observations addressed the kinds of supports, resources, and practices teachers at a STEM-focused elementary school believe are critical in promoting STEM goals. These interview data were simultaneously collected and analyzed (Merriam, 2009) throughout the data collection process. The data were analyzed according to published suggestions for analyzing qualitative data by Hycner (1985) and Merriam (2002). The steps involved in analysis are summarized in Table 3 and include: (1) transcribing interview data; (2) listening to interviews in their entirety while reading transcripts multiple times and jotting notes or adding to existing data memos. This step allowed for the opportunity to interpret meanings in non-verbal communication such as intonations, emphasis, and pauses (Hycner, 1985); (3) compiling interview text into NVivo Qualitative Research Software to aid in coding and analysis; (4) reducing the data to broad codes or units of general meaning of participants (Hycner, 1985) using open-coding methods described by Saldana

(2013). Condensing data in this manner was valuable as it allowed for an organizational procedure that aided in making sense of the ideas that emerged from individual participants as well as from across the entire corpus of data (Perakyla & Ruusuvuori, 2013); (5) consolidating general units of meaning into themes to address research questions using pattern coding as suggested by Saldana (2013). This step allowed units of general meaning to be further contained to more specific and precise themes that specifically answered or addressed research questions; (6) using critical colleagues to aid in verification of findings. Employing such strategies were not only a helpful check, but it strengthened the rigor of this research project (Hycner, 1985); (7) summarizing each interview through the lens of the established themes; (8) collecting new data from follow-up interviews that were analyzed following the steps previously mentioned; and (9) constructing a narrative that captured the essence of beliefs, practices, and other characteristics of teachers at a STEM-focused elementary school.

Table 3: Summary of analysis procedures

Procedure number and name	Description of procedure
1. Transcription	Convert interview audio to written text.
2. Listen/Read	Listen to audio and read transcript of interview in its entirety several times to gain a sense of the whole.
3. Compilation	Transfer transcript into NVivo.
4. Reduction	Reduce data to codes or units of general meaning of participants (Hycner, 1985) using open- or

	initial- coding (Saldana, 2013).
5. Themes	Collapse individual codes together to form themes using pattern coding (Saldana, 2013) that may be used to address research questions.
6. Critical Colleagues	
7. Summarization	Employ other researchers to verify findings.
8. Follow-Up	Write summary of each interview, incorporating elicited themes (Hycner, 1985).
9. Construct Narrative	Collect new data through follow-up interviews and analyze using previously discussed procedures. Construct a narrative to capture the essence of phenomena being studied.

Chapter Four: Findings

Supporters of STEM education have repeatedly pointed out the need to identify components of STEM-focused schools that facilitate, moderate, or constrain success in STEM in the hopes of creating learning environments that effectively prepare students in STEM disciplines (Erdogan & Stuessy, 2015). To date however, we know very little about components of STEM-focused elementary schools. Most STEM school research remains focused on the outcomes at the high school and postsecondary level (Wells, 2013).

This study used a qualitative approach to document the salient practices of teachers who teach at a STEM-focused elementary school. In-depth, semi-structured interviews addressed three main research questions. The first question examined how factors related to teacher preparation, beliefs, and supports and barriers to teaching science for teachers at a STEM-focused elementary school compare to a larger representative sample of elementary teachers in California. This question was analyzed using a survey that asked participants to describe their teaching practice, preparation, and supports offered. These survey data were then compared to survey results of teachers at 300 randomly chosen elementary schools across California.

The second research question sought to highlight instructional practices that teachers at a STEM-focused elementary school report as promoting STEM learning. This

question was examined by asking interviewees about practices they believed necessary for teaching and learning in a STEM-focused elementary school. In general, these practices are among a list of contextual factors within the school ecology framework and contribute to the school experience. While some of these practices were pedagogical choices regarding the way content was delivered to students, others described the ways in which teachers acted as influential facilitators in strengthening or developing students' identity as learners.

The third research question examined the supports and resources teachers at a STEM-focused elementary school identified as critical in developing and promoting STEM teaching and learning. Interviewees were asked several questions about the various supports and resources used and offered that affected their teaching practice. This analysis sought to highlight the kinds of things teachers identify as necessary for maintaining or improving their sense of self-efficacy in teaching STEM concepts.

This chapter presents the key findings of the research and begins with a portrait of the site school. Next is a summary of the survey findings. This is followed by results of the qualitative findings. These qualitative findings are organized into three main themes: (1) doing STEM; (2) being STEM; and (3) wanting more.

Portrait of Madison Elementary School

Throughout the fall of 2015 and spring of 2016, I visited Madison Elementary School (pseudonym) a total of fifteen times to attend staff meetings, conduct interviews,

observe classroom lessons, or recruit participants. As I became a regular fixture around campus, I was invited into more and more classrooms. “You can come observe my class anytime,” became a frequently uttered statement.

When I arrived for my first visit to Madison, the marquee at the school entrance reminded parents, students, and community members about that week’s upcoming science night. I parked in the small parking lot for visitors at the front of the school and went to the school office. The office was dated and cramped. Two staff members worked in the office, answering phones, helping students, and parent volunteers to appropriate locations. I introduced myself to the secretary and she phoned Ms. Principal (pseudonym) to let her know I had arrived. Ms. Principal emerged from a doorway at the back of the office. She put her hand out to shake mine and introduced herself. Then she motioned for me to follow her to her office. We sat for close to an hour, discussing the particulars of my study. Ms. Principal expressed her excitement to be involved in the research study and then invited me on a tour of the campus.

As Ms. Principal led me around the campus, she introduced me to staff members and teachers. I used the opportunity to tell people about my research project and inform them that I teach elementary school. Ms. Principal showed me the school garden. She explained the garden is maintained by students and provides a working laboratory for students to engage in extended investigations. Ms. Principal took me to several classrooms where instruction was occurring. For the most part, the campus buildings were

outdated and in need of repair. There were a few portable classrooms to accommodate increasing enrollment. The school had a small baseball diamond, small field of grass, a playground for outdoor activities, and a basketball court. I was told that the school lost a small playground that had playground structures for climbing and playing to make room for the two new buildings. We ended the tour with a visit to the school's new construction project. Slated to open in January 2016 were two new buildings; one housing two science labs and second with two classrooms. Staff and students expressed excitement about the opening of these new buildings. These two new buildings would house two science laboratories and two new classrooms. Ms. Principal then invited me to return the next week to attend a staff meeting and meet classroom teachers.

I returned the next week to attend the weekly staff meeting. The teaching staff was noticeably diverse and included men and women representing many different ethnicities. Later Ms. Principal told me she had worked very hard to assemble a diverse staff that represented the students who attended Madison. I introduced my project and my own teaching career. The school gym shared a wall with the staff meeting room. Throughout the meeting, you could hear thumping through the wall as students participated in after school basketball practice. After the meeting concluded, several teachers came to personally welcome me to the campus and express interest in participating in the project.

Over the course of the next several months, I saw student projects adorning the walls and windows of classrooms and hallways of the school. On display in one

classroom were student projects examining how light affects the germination of plant seeds. In another classroom, kindergartners were measuring the growth of grass seed. I watched a first grade classroom build sundials with paper plates, clay, and pencils, then go out to a sunny patch of concrete and place their creations, returning several times throughout the day to collect their data. Students in a sixth grade classroom worked collaboratively to create an informational brochure to educate the community on how to prepare for an earthquake. Their brochures included information about what causes earthquakes as well as historical information about past earthquakes. While it was expected that hands-on science activities would occur in the school's science labs, the active engagement of science was also clearly happening within the classrooms across the campus.

Survey Findings

In 2011, researchers from the Lawrence Hall of Science at the University of California, Berkeley along with SRI International conducted research examining the status of science teaching and learning in California public elementary schools. These researchers administered the Science Education Survey of Elementary School Teachers to 775 randomly selected elementary school teachers in 300 randomly selected elementary schools in California. Seventy-percent of selected teachers completed the survey. These teachers answered questions about their teaching of science, preparation, and the support they receive in teaching science. These researchers concluded that, “children in

California elementary schools rarely encounter high-quality science learning opportunities because the conditions necessary to support them are rarely in place” (Dorph et al., 2011, p. ix).

I administered the same survey to teachers at Madison Elementary School. Twenty-four participants that included curriculum specialists and teachers in kindergarten through grade six were invited to participate in the survey. Fourteen of the twenty-four responded, a 58% response rate. Table 4 provides a summary of the range of respondents. The purpose for administering the exact same survey was to examine the ways in which teachers at Madison Elementary School are similar to and different from California elementary school teachers in general.

Table 4: Summary of survey participants

	Kinder	First	Second	Third	Fourth	Fifth	Sixth	Technology Specialist	Science Specialist	
Number of respondents	2	2	1	2	1	2	2	1	1	14
% of total	14%	14%	7%	14%	7%	14%	14%	7%	7%	100%

As part of the survey, teachers were asked to describe the kinds of practices used in the classroom to provide learning opportunities to students in science (Dorph et al., 2011). These practices were organized into three categories: foundational learning experiences, practices of science, and language learning. Table 5 provides a summary comparison of these practices.

Table 5: Summary comparison of science teaching practices

Practices that provide opportunities to:	Always/Often		Sometimes		Rarely		Never	
	Madison	CA	Madison	CA	Madison	CA	Madison	CA
Foundational learning								
Answer textbook or worksheet questions	64%	32%	7%	47%	14%	13%	14%	7%
Read textbook	50	48	14	34	0	10	36	8
Watch demonstration	43	36	36	54	21	8	0	2
Listen and take notes	23	33	38	33	8	14	31	20
Watch audio-video presentations	21	30	50	53	29	13	0	4
Practices of science								
Do hands-on activities	71%	42%	14%	40%	14%	16%	0%	2%
Work in groups	71	65	29	30	0	4	0	1
Record or analyze data	43	29	57	49	0	17	0	5
Do fieldwork	21	3	50	18	21	30	7	49
Design investigations	14	7	29	31	57	38	0	25
Language learning								
Read non-textbook materials	36%	30%	36%	51%	7%	16%	21%	3%
Write reflections	36	24	36	42	14	24	14	11
Present to the class	14	10	43	38	36	32	7	21
Write reports	14	6	36	30	29	36	21	15

Adapted from "High Hopes-Few Opportunities: The Status of Elementary Science Education in California." by Dorph et al., 2011, Sacramento, CA: The Center for the Future of Teaching and Learning at WestEd.

Dorph et al. (2011) and others (National Research Council, 2011; Duschl et al., 2007), emphasize that none of these practices alone indicate the quality level of science instruction in elementary school classrooms. However, science is learned best by actively engaging in and experiencing the practices of science, including practices such

as identifying and conducting investigations, doing fieldwork, sharing ideas, writing, and analyzing data. Like other California elementary school teachers, Madison respondents reported that group work and hands-on activities are their most frequently used strategy for engaging students in the practices of science. Fewer than half of the surveyed California teachers claimed to always or often use hands-on activities as their primary method of science instruction. In contrast, most (10 of 14 [71%]) Madison teachers claimed to always or often use hands-on activities to engage students in science learning. Furthermore, less than 25% of teachers across the state reported always, often, or even sometimes doing fieldwork as part of their science instruction. That means that nearly three-quarters of the California teachers surveyed never or rarely provide students opportunities to participate in fieldwork. In contrast, nearly three-quarters (10 of 14 [71%]) of Madison participants reported always, often, or sometimes providing students fieldwork opportunities.

Teachers at Madison reported feeling as under-prepared as other California elementary teachers statewide (Figure 2) when asked to describe their confidence regarding the use of specific instructional practices. For example, when asked about how equipped they feel to use inquiry or investigation-oriented teaching strategies, 26% of California elementary teachers reported feeling very well prepared and (4 of 14 [28%]) Madison teachers reported feeling similarly. However, most (12 of 14 [86%]) of the Madison respondents indicated that inquiry-based professional development is very or

fairly important, yet only a few (3 of 14 [21%]) felt inquiry-based techniques were actually emphasized during district or site-based professional development opportunities offered over the past three years.

Figure 2. *Comparison of Reported Preparedness in Science Instruction Practices*

Although 29% of California teachers statewide reported feeling very well prepared to integrate science content into other school subjects, only 1 in 3 of those teachers reported actually integrating science. On the other hand, a similar percentage (5 of 14 [36%]) of Madison respondents indicated feeling as prepared to integrate science content, yet a majority (13 of 14 [93%]) of Madison surveyed teachers reported actually integrating science with other disciplines.

When asked about the number of science instructional minutes offered to students, Madison teachers differed from California teachers by offering more minutes. For example, 40% of elementary teachers statewide reported offering 60 minutes or less of science instruction per week, with 13% of those teachers reporting providing 30 minutes or less of science instruction per week. Conversely, Madison respondents reported 120 minutes as the minimum number of science instruction minutes per week offered to students. Consider that only 10% of kindergarten classrooms statewide indicated providing as many instructional minutes in science as is typical in a Madison kindergarten science classroom. Furthermore, about half of surveyed California fifth grade classrooms provided their students with 120 or more minutes of science instruction per week. However, a typical Madison fifth grade classroom offered students at least 200 minutes of science instruction per week. Figure 3 shows Madison teachers' reported integrated science instructional minutes compared to the average integrated science instructional minutes per week of teachers statewide. When science is often or sometimes integrated into other school subject, surveyed California teachers reported an average of 101 weekly instructional minutes in science.

Figure 3. Weekly integrated science instruction minutes for Madison teachers

California has a specific framework for science learning that includes California Science Standards (CSS) (Curriculum Development and Supplemental Materials Commission, 2004). Madison teachers reported feeling nearly as prepared as surveyed California elementary teachers to align curriculum to the current California Science Standards, 57% and 54% respectively. This current science framework, however, is undergoing a revision with the recent adoption of the California Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve (CA NGSS) (California Department of Education, 2015). These new criteria for science learning will be fully implemented in California science classrooms by 2018. When asked to describe how prepared they feel to address these new criteria, very few (1 of 14 [7%]) Madison respondents felt very well prepared to align curriculum to the upcoming Next Generation Science Standards. All (14 of 14 [100%]) of the Madison respondents

indicated that deepening their own understanding of the NGSS was fairly important or the most important professional development topic necessary for becoming an effective science teacher.

For the most part, elementary school teachers rarely have training in science content beyond the courses required for credentialing (Fulp, 2002). For example, only 4% of elementary teachers nationally have undergraduate degrees in science or science education (Fulp, 2002). California elementary school teachers have even less science training with only 1.4% having a bachelor's or master's degree in a science discipline (Dorph et al., 2011). However, more than one-third (5 of 14 [36%]) of Madison teachers surveyed reported holding an advanced degree in a science discipline.

Though Madison participants reported feeling as equally prepared to teach life, earth, and physical sciences as California teachers in general (Figure 4), they reported feeling less prepared to teach English language arts, mathematics, and social science than their statewide counterparts. Whereas, ninety percent of California elementary teachers in general reported feeling very prepared to teach English language arts, only about half (8 of 14 [57%]) of Madison participants felt the same. Because Madison does not use kit-based science curricula, it was not surprising that very few (1 of 14 [7%]) participants indicated feeling very well prepared to use such resources. On the other hand, 31% of California teachers in general felt very well prepared to use kit-based science curricula.

Figure 4. Comparison of Teachers' Reported Preparedness to Teach Various Subjects

Section Summary

Science is best learned through practices that promote active engagement (Dorph, et al.). Surveyed Madison teachers indicated that they use more of these practices more often than other California elementary school teachers do. Madison teachers also reported providing students more minutes per week in science instruction than California teachers in general. Whereas California science classrooms in general reported providing students an average of 102 integrated science instruction minutes per week, the minimum weekly science instruction in Madison classrooms is 120 minutes. One reason for the increased instructional minutes is integration. Though only one-third of surveyed

California teachers reported integrating science into other subject areas, every Madison surveyed teacher reported integrating science into at least one other content area.

Further, while only 1.4% of California elementary school teachers hold a Bachelor's or Master's degree in a science discipline, more than one-third (5 of 14 [36%]) of surveyed Madison teachers claimed to hold such degrees. Lastly, Madison teachers reported feeling less prepared to teach English language arts, mathematics, and social science than California teachers in general.

The qualitative findings that follow provide confirmation of many of the practices teachers reported using in the survey. Additionally, while many of the topics discussed in the survey focused on how teachers deliver content or provide experiences to students for acquiring scientific knowledge, the qualitative sections that follow expands on this list to include practices that promote confidence in STEM content areas.

Qualitative Findings

Open coding was used to generate a coding scheme for interview transcript data (Saldana, 2013). Three primary themes emerged from the coding (1) doing STEM; (2) being STEM; and (3) wanting more. Table 6 summarizes these main themes and subthemes.

Table 6: Study themes and sub-themes

Main theme	Doing STEM	Being STEM	Wanting more
Subthemes	Hands-on & Project-based learning	School culture	Communication and collaboration
	Integrating content	Teacher STEM	
	Student choice	School-wide practices	Clear STEM vision
	Student collaboration	Classroom practices	Professional development
	Learning beyond the classroom	Talking about science	
	Not using direct instruction	Intentional support for underrepresented students	Community involvement

The first theme, “doing STEM” focused on the practices teachers reported important for promoting STEM teaching and learning. These practices focused on the learning environment and the ways in which teachers provided learning experiences for students. The second theme, “being STEM” highlighted the ways in which teachers supported students’ development of a STEM identity by building or strengthening confidence and self-image in regard to STEM content areas. The third theme, “wanting more STEM” came about as teachers described their experiences teaching in a STEM-focused elementary school. While a majority of teachers described their school in positive terms, they all indicated the quality of the STEM experience offered to students

could be improved by providing teachers more opportunities to strengthen their own practice.

Participant Profiles

Seven semi-structured qualitative interviews were conducted with Madison teachers. Their teaching experience ranged from 1 to 26 years. Three currently hold a Bachelor's degree and four hold a Master's degree. Two of the seven (28%) hold a degree in a science discipline. Table 7 provides a summary of participants' characteristics.

Table 7: Summary of interview participants' characteristics

Pseudonym	Grade	Gender	Years teaching	Education
Kennedy	Kindergarten	Female	3*	BA-Liberal Arts
Taylor	First	Female	1	MS-Liberal Studies
Casey	Second	Female	5	MS-Environmental Science
Ryan	Fourth	Female	20	MS-Curriculum and Instruction
Peyton	Fifth	Male	26	BS-Sociology MS-Educational Leadership
Reagan	Sixth	Female	6	BS-Liberal Studies
Morgan	Science Specialist	Female	26	BS-Physical Science

* Kennedy taught preschool for 8 years prior to teaching in public education.

Kennedy-Kindergarten

Kennedy has been teaching kindergarten as an intern teacher for the past three years while completing credentialing courses at a California State University in northern California. Before taking on this position full-time, she was a substitute teacher for the school district in grades kindergarten through twelve and served as a temporary science lab teacher at Madison. She assumed her current position after filling in as a long-term substitute. Before becoming a kindergarten teacher, Kennedy taught preschool for eight years.

Taylor-First Grade

Taylor is a first year teacher currently teaching first grade. She found her way to Madison right out of her northern California State University credentialing program.

Casey-Second Grade

Casey has taught elementary school for five years. Her first two years were in the early 2000s, after which she took time off to have children of her own. She returned to the classroom three years ago. Even though she has five years teaching experience, Casey would tell you she is a new teacher because this is her first year teaching second grade. Prior to teaching second grade, Casey taught kindergarten.

Ryan-Fourth Grade

Ryan has been teaching fourth grade for four years. Her career spans 20 years teaching in elementary schools in California for three different school districts. She

earned her Bachelor's degree from California State University in southern California. She then received her Master's degree in curriculum and instruction from a northern California State University.

Peyton-Fifth Grade

Peyton has been teaching fifth grade at Madison for 26 years. He earned his Bachelor's degree in sociology and then his Master's in educational leadership. He also has his administration certificate.

Reagan-Sixth Grade

Reagan has been teaching for six years. This is her first year teaching in an elementary school setting. Prior to teaching at Madison, she taught high school biology for five years. In addition to having a multiple subject credential to teach elementary school and a credential in biology, she holds an additional single subject credential in health science.

Morgan-Science Specialist

Morgan has been working at Madison as a Science Specialist for the past 9 years. She manages and teaches from one of the two newly constructed science labs. She teaches the hands-on science labs for fourth, fifth, and sixth grade classrooms two times per week. She also provides science lab instruction for students who attend the school's special day class. Morgan has a Master's of science in physical science and has been teaching for 26 years. Prior to teaching at Madison, Morgan taught high school science

for eight years. The remaining 18 years of her teaching career have been spent teaching science at elementary schools in the district to which Madison belongs.

Dedicated science lab space is not typical in the elementary school setting. With two brand new science labs, Madison is different. Although Morgan provides lab experiences to students in grades four, five, and six, another science specialist provides lab instruction to first, second, and third grade students one time per week. The science lab rooms have large picture windows, lots of counter and storage space, a white board, and connectivity for audio and visual presentations. Looking more like a high-school science lab or a natural science museum, the walls and counters are adorned with animal skeletons, insect collections, terrariums, aquariums, and an ongoing student experiment here and there. The cabinets and drawers overflow with supplies procured by Morgan, donated by families, or provided through grants made by the school's parent Science Committee. There is seating for thirty-two students at four clusters of tables that face the front of the room. These tables serve as the discussion area where Morgan presents information and instructions for students. Students can easily turn and talk while Morgan hops from group to group. After instruction, students move to lab tables that line the perimeter of the back of the lab to conduct their experiments. These lab tables are taller, allowing students the choice to work sitting or standing.

I sat in the back of the lab at a set of lab tables, listening to the swarm of silk worms in a tub munching on leaves, watching the students pass metal sheet pans and

large plastic trays back and forth discussing the perceived hotness or coldness of each with their neighbors. Then the school's student science officers shouted an announcement over the p.a. system: "Hello Madison staff and students. Today's science fact..." The announcement caught me off guard and the only thing I could make out was something about Ganymede and the planet Jupiter. Then the treasurer reported how much money was raised at a recent fundraiser. The announcement ended with one last science fact. At the conclusion of the announcement, Morgan got the students' attention and reminded them about their investigation in progress. Students were testing the insulating properties of various materials. She then posted a table of temperatures that were collected. Students recorded the data and then worked with their group partners to graph the data. Morgan then asked them to talk among their table group about what the data and the graph say about the insulating abilities of the materials. Chatter broke out at each table. Morgan walked among the groups listening to the conversations. After several minutes, she interrupted students to say, "When I as a kid, my mom told me to wrap everything in aluminum foil. Was that a good idea?" Students respond by shouting, "No!"

"Why not?" Morgan asked.

"Because it had the highest temperature. It didn't keep the can cold," claimed a female student. Morgan then directed the students to use the data to decide which material would be the best insulator.

After several minutes of students talk, Morgan wrapped up the conversation and moved the group on to the next activity. She passed a metal sheet pan and a plastic tray to each table group and asked each group to decide which tray, the metal or the plastic, was colder. “So, which is colder?”

Several students shout that the metal tray is colder. One student at the table in the back of the discussion area mumbles to his partner that the trays are the same temperature. Morgan heard the student’s response, “They are the same temperature? What do you mean by that? What makes you think that?”

“Well they are in the same environment, so they are the same temperature,” the student sheepishly states.

“Does that make sense, what he said? That these are the same temperature?” Morgan asks the class.

“But the metal feels colder,” another student protests.

Morgan asks table 1 to turn their trays over and report what is there. Taped to the underside of each tray is a thermometer. Morgan explains that she placed the thermometers earlier in the day. “Can you read the temperature on the thermometers?” A student from table 1 read the temperatures out loud to the class, “22 degrees.” Morgan then walks the trays with the thermometers around for each table group to examine. The class then discusses the idea of room temperature. Morgan then moved to the front of the room, presses a button that lowers the window shades to make the room dark, and tells

students that they would be watching a short video. She told them to be ready to share something interesting from the video with their partner when it was done. The video showed a man on a London street asking adults to touch a metal computer hard drive and a paperback book and then state which was warmer. All the adults in the video claimed the book was warmer. The man in the video then went on to explain room temperature and conduction. The video ends and the shades rise. “Turn and tell your partner one interesting thing you noticed about the video,” Morgan tells the class.

Next, Morgan tells the students their lab task, “If things that have been in the same environment are the same temperature, will a metal spoon and a plastic spoon melt an ice-cube at the same rate?” She sends students to their lab tables. After students examine the bins of silk worms at their lab tables they settle and Morgan gives them a metal spoon and a plastic spoon, a towel, and two ice-cubes. She then instructs them to place an ice-cube in each spoon and then closely observe what happens. As groups are working, Morgan walks around the room and asks each group to describe what they see. “The ice is melting faster on the metal spoon,” one group tells her in a whisper, like their observation is a secret to be kept from the other groups. “Why?” She asks the group. “Because the metal spoon is conducting heat to the ice faster,” a female student says. Morgan slaps each group member a high-five. She continues around the room, high-fiving each member as they connect melting faster to the idea of conduction. Morgan then sends the students back to their discussion tables to record their ideas into their

science journal. She cleans up the science supplies and then dismisses students to their homeroom class.

As this class exits the lab, another is waiting at the door. Morgan will then repeat this discussion and lesson with another class. While Morgan has students, the classroom teacher gets a prep period. Explaining why Morgan's position is sometimes referred to as a science prep teacher. Morgan explained that the school also has a computer lab with a computer specialist. This specialist conducts technology classes that allow the classroom teacher another prep opportunity. These specialists make it possible for classroom teachers to receive a 50-minute prep period every day of the week.

During participant interviews, teachers talked about the role the science lab plays in providing learning experiences in science. They expressed how the lab provides two important functions. The first was to ensure that students participate in science lab experiences. The second was to provide students learning experiences that occurred outside the general education classroom. Second grade teacher Casey explained,

In the science lab, they're [students] excited to go to another room to do it. That "official" science just makes it a little more scientific for them. They get excited to just observe when they go there. It's an experience. Taking kids outside the regular classroom and into the lab, it just inspires them differently because it's different.

The lesson described above lasted for 50 minutes and is an example of what Morgan reported as a typical lab experience that fourth, fifth, and sixth grade students receive two times per week. As the school's science specialist, Morgan is only responsible for delivering science content. This singular focus is not typical of elementary school teachers who are generally responsible for delivering content in multiple subject areas. As such, Morgan's role and goals as a science lab teacher are very different than the typical Madison classroom teacher. For this reason, she is represented much less than other participants in the sections that follow. However, the science lab and the science specialist represent significant components of the school ecology. Therefore, I felt it important to present a glimpse of these particular contextual factors.

The sections that follow present the themes that emerged from the in-depth participant interviews. Each of the sections begins with a summary table of the coded data to provide evidence of rigor for the themes and subthemes that emerged. This is followed by a participant quote that I believe captures the sentiment of the theme. I then explain the theme, highlight important subthemes, present data excerpts, and discuss any similarities or valuable dissonance among participants.

Practices that Promote STEM Teaching and Learning: “Doing STEM”

From what I’ve seen elsewhere, here it’s a lot more hands-on with science and they [students] use a lot more technology. It’s just different because it’s hands-on and they’re doing a lot more experiments and they’re researching and they’re doing big projects, even in first grade.

-Taylor (1st Grade)

Table 8: Coding tally chart for reported content delivery methods. Each value represents the number of times the subtheme emerged during participant interview.

Pseudonym Grade	Doing STEM					
	Hands-on/ Project-based learning	Integrating content	Student choice	Student collaboration	Learning beyond the classroom	No direct instruction
Kennedy Kindergarten	22	20	11	7	3	12
Taylor 1	20	6	4	2	1	3
Casey 2	9	3	0	0	4	3
Ryan 3	20	5	11	3	0	6
Peyton 5	13	8	0	0	0	0
Reagan 6	12	18	3	3	2	7
Morgan Science Specialist	12	6	0	4	0	3

Taylor’s comment highlighted that while teachers may use many strategies for STEM teaching and learning, some practices were reported to be used more often than others. Table 8 shows the coding results in the form of coding tallies to demonstrate the

extent to which participants expressed methods for engaging students in subject matter. All of the interview, as well as survey, participants expressed their desire for students to “do STEM” in more hands-on. Teachers reported that doing science in ways that were more engaging for students was “real science.” As Madison teachers described how they provide opportunities for students to “do STEM,” they commented, “I have them get up and walk around and act it out,” or added that, “The science here is real and it’s not out of a book,” or stated, “I’d rather my kids do hands-on stuff,” and that “I think science needs to be hands-on to be real science.”

Participants clearly indicated that hands-on is what they consider “real science.” Peyton summed up this sentiment enthusiastically with a slap on the table, “You know there is more hands-on because that’s really where science is!” On this same topic, Reagan suggested that this idea of hands-on making content “real” actually goes beyond science to include all STEM subjects, “I think that’s a big thing for STEM, you know being involved.” Furthermore, when a particular lesson or experience provided for students does not meet this definition of “real science,” teachers express disappointment. Take for example Casey, who recalled a lesson from weeks past that did not live up to her expectation of “real science,” “You know, one time I was so sad when I didn’t have magnets for them [students] to touch and manipulate and use. We had to talk about magnets instead and it just wasn’t the same.” The disappointment she felt in not providing her students with a genuine hands-on experience appeared to weigh on her,

“Well, I guess I could have brought stuff from home. It seems that it could be done differently next time and really be an experience.”

Furthermore, Madison teachers felt that hands-on experiences were necessary preparation for their students’ futures. Taylor stated, “Where I think it [hands-on] helps them is that it prepares them for their future. Like if they want to be an engineer. These kinds of experiences show them like, ‘Oh, this is how you build things.’” Sixth grade teacher Reagan expressed a similar sentiment, “These kids are learning stuff that they are going to use in jobs that aren’t even around yet, and I strongly believe that this is stuff that they’re going to need.”

Project-based learning emerged among all participants as an example for providing students hands-on learning experiences. When asked the kind of hands-on experiences provided to students in the classroom, Reagan explained, “Kids are doing a yearlong—each grade level has a yearlong project that they do. PBL [project-based learning] is how I try to teach. It’s a philosophy of learning through problem solving. The only way we learn is by doing and experimenting.” For teachers, experiments were seen as learning experiences that could be completed frequently, often within a class period or two, projects were experiences that extended over longer periods. Kennedy explains it as, “Every class is doing some big science project with our garden that lasts for several months. Second graders are doing silk worms and butterflies. Third graders collect insects and fourth graders study the effects of composting. I think that’s so

awesome!” Rather than feeling forced into these extended projects, Madison teachers appeared to embrace the practice. Take for example the way first grade teacher Taylor, who is also a first year teacher, highlighted the use of projects:

There are a lot of projects and activities where it's like here's the question I want you [students] to figure it out. Why do you think this? How did you get that answer? They have to do it by themselves. Sometimes it's a big project that they're going to present at open house. It's very different than what another kid might experience at a different school.

Projects not only provided hands-on learning experiences for students, they also seemed to afford teachers opportunities to incorporate engineering principles into the curriculum. Ryan acknowledged the absence of engineering from the elementary school curriculum. She stated, “I don't even know if we say engineering enough. We should say it more because some kids don't even know what engineering is.” She went on to explain that while no one is teaching her about engineering principles specifically, she finds ways to provide engineering experiences in projects, “They're constructing explanations for science and designing and testing solutions. I think sometimes that kids are like, ‘Oh, I did this!’ That's engineering. But, they don't maybe know that.” Taylor acknowledged that one problem with engineering content in the elementary grades is because elementary teachers find engineering an intimidating topic, “Engineering scares

elementary school teachers.” Nonetheless, she too explained how projects provide opportunities to engage in engineering,

Engineering doesn’t have to be an engineering lesson. You can incorporate it into a lot of things. Like our local project they’re [students] engineering is building the paper plate with the Play-Doh. They’re building things. They’re drawing and planning. They’re doing it all.

Although every interview participant expressed a desire to provide hands-on learning experiences for students, some teachers described encountering barriers that prevented them from teaching in the manner they wanted. A few teachers described not having the resources in the classroom, not having enough time to teach hands-on lessons, or not having the space to conduct science experiments. Casey, a second grade teacher, captures this disconnect between how she wants to teach and how she actually teaches,

When I teach science, sadly it’s just okay. I wish it was more interesting than just here’s the textbook, here’s the vocabulary, let’s talk about it, take your books home, here’s your science homework bring it back when you’re done. But, that’s how it is. That’s how my science lessons are. Sad isn’t it! That doesn’t feel like the science that should be a science magnet. But, the hands-on is over there [science lab]. I don’t do lab. I wish I could. I just don’t have the materials. And it takes so long.

Ryan expressed the same sentiment that hands-on is “over there” in the science lab. When asked about the hands-on activities provided to students, she stated, “They go to Morgan [science specialist] for lab experience because I can’t. In the classroom, that’s the part that’s hard. It’s just really hard in the classroom to provide that experience with everything else that needs to be covered.”

Integration of content was another practice described by all participants as important in promoting active environments for STEM teaching and learning. Every participating teacher indicated that they integrate subjects to some degree as part of their regular practice. Some teachers described integration as simply selecting books with science topics for use in English language arts. When discussing integration, kindergarten teacher Kennedy explained,

For example teaching English language arts, instead of picking any random book, it will be an informational book for example about penguins. We’re what is the main idea of the story, what are the characters? We’re looking at these different things but through science content. So, it’s kind of two-fold, teaching science at the same time I’m teaching English language. It’s just very much, you know, interwoven, the two subjects.

On the other hand, some teachers described integration as combining multiple content areas together. Peyton describes how integration became an important part of the school’s transition from a traditional elementary school to a science magnet,

How are we going to incorporate everything together? That was a really big thing in the beginning because we traditionally had all the subjects separated. Now all of a sudden we're bringing science into the forefront. We incorporate science and technology, math and science. We incorporate language arts and science. It's presentation, it's science, it's technology. It's bringing grammar into social studies.

Although integration was reported by all participants as a school-wide practice to increase access to STEM content, actual implementation was described by some as difficult and that the practice may never be fully realized. Peyton pointed out that, while he believes his school is more successful at integration than other schools, there is always more to do,

We are further along than other schools. But, there's a lot to grow on. It takes a while. As a science magnet school the goal is for science to be in everything we do. We're still trying to strive. You know, you get your feet wet and like be good at one thing and then next you're good at a couple things.

While not as universal as hands-on activities and integration of content, other active learning strategies were reported by enough of the participants to be notable. For example, four participants reported student choice as an active learning environment. Other additional practices included student choice, collaboration among students, and learning beyond the classroom.

Student choice was a strategy that was particularly important to kindergarten teacher, Kennedy and third grade teacher, Ryan. Kennedy expressed value in allowing students some ownership in their learning, “A lot of my teaching comes from the kids and their interests and where I see their thinking going. I think that allowing your students to lead your teaching is very important.” She summed up her feelings about student choice saying, “If you don’t allow it to happen then it kind of robs them [students] of the experience and it doesn’t allow them to foster and continue their learning.”

Ryan, fourth grade teacher and twenty-year veteran, allowed students to choose when they work. She excitedly described how student choice plays a role in her Language arts instruction,

I use a daily five program for language arts. Our district is beginning to offer PD [professional development] after school. Which is great because there are other STEM schools that are using it. But, basically it’s all about choice and not always having centers that are planned. The kids can do reading and if they’re reading, they can read whatever they want. If they choose writing then they’re working on that. They can do science research work; they can do scientific words that they want to learn about. This is where I incorporate extra science. I mean it’s very open ended. The great thing about it is the kids love it so much because they are choosing. But, if you’re always just doing it out of a book, you never have that.

While the practices discussed by participants thus far were strategies in which participants described using within the classroom to provide students learning experiences, direct instruction emerged as an instructional practice intentionally avoided by most participants. Teachers steered clear of this teacher-centered practice for either of two reasons. The first reason reported was that this practice goes against the student-centered philosophies these teachers hold. For example, Taylor explained that she avoids direct instruction because, “You should let them learn rather than teach them.” Ryan described it as an “old” style of teaching. She stated, “Direct instruction, the old style of sage on the stage-the teacher in charge, is going aside. We lose a lot of kids that way, especially at this age.” Kennedy admitted that direct instruction might have a place in education, but not with elementary school students, “I avoid direct instruction. I guess because it’s always pretty much going to be a failure. Maybe like in college, or high school, maybe junior high you can get away with it more. But, for elementary, absolutely not. You lose your audience fast.”

The second reason teachers offered for avoiding direct instruction was their own past learning experiences. Taylor simply recalls, “From what I grew up with, we never did big projects. Now I teach a lot more hands-on and use a lot more technology.” Kennedy’s personal experience being educated in direct instruction classrooms was much more uncomfortable. She recalls how this type of teaching not only affected how she felt about school subjects, but also is part of her inspiration for teaching differently,

I remember being in school and not caring for science. The way I was raised was all direct instruction. I mean I was raised on direct instruction classrooms. The way I was raised absolutely has a lot to do with the way I teach now and wanting to teach in a school like this. Seeing it taught in a different way, very hands-on, is great!

This section described several of the practices teachers reported as promoting STEM teaching and learning. The practices described were student-centered and provided students with experiences that were “active” in nature. Hands-on and integration were among the practices universally reported by participants, while student choice, collaboration, and learning beyond the classroom were reported by fewer participants. An interesting finding was teachers’ reported avoidance of direct-instruction as a practice to promote STEM teaching and learning.

Practices that Promote Students’ STEM Identity: “Being STEM”

“There’s more to STEM than just people in white lab coats in a lab doing a lot of experiments and making explosions”

-Taylor (1st Grade)

Table 9: Coding tally chart for practices reported as promoting STEM attitudes and dispositions. Each value represents the number of times the subtheme emerged during participant interview.

Pseudonym Grade	Being STEM					
	School culture	Teacher STEM	School-wide practices	Classroom practices	Talking about science	Specific support for URM students
Kennedy Kindergarten	21	17	4	7	3	18
Taylor 1	10	10	2	3	2	7
Casey 2	8	6	7	5	0	3
Ryan 4	17	12	20	5	3	8
Peyton 5	21	3	14	5	3	8
Reagan 6	5	6	4	3	2	7
Morgan Science Specialist	4	5	4	6	2	5

While the previous theme described strategies used by teachers to engage students in learning content, this theme describes ways in which teachers supported the development of confidence, self-image, attitudes, or dispositions of students in STEM content areas. I labeled this theme “being STEM.” Table 9 shows the coding results in the form of coding tallies to demonstrate the extent to which participants expressed practices for “being STEM.” Although I chose to label this theme “Being STEM,” others have described this concept as a STEM identity. Though related to science identity, a construct established in recent literature (Barton et al., 2013), STEM identity extends beyond science to include technology, engineering, and mathematics. In general, a

STEM identity refers to the degree in which a student perceives herself as competent and confident in a STEM discipline (Paulger, 2015). Taylor's comment above exemplified the idea that STEM is more than just learning about science, technology, engineering, and mathematics. STEM is also about doing by providing opportunities for students to act like scientists, mathematicians, or engineers.

All Madison teachers suggested that promoting a STEM identity by "being STEM" begins with the overall school culture. Interviewees suggested that the STEM-focused beliefs and values of the school as a whole contributed to STEM attitudes of all members of the school community. In other words, the more valuable the school believed STEM literacy to be, the stronger and more persistent the STEM attitudes its people. Morgan, science specialist, for example, highlighted the collective value placed on science, "As an entire community, we have a greater focus towards science. We want them to love science." Fifth grade teacher, Peyton further described how science and technology are valued throughout the school organization,

We're just really unique. We're a science technology school. Science is important to us. Science is incorporated and technology is incorporated. Before we actually had a "lab," the staff decided we needed a science lab. We couldn't have our science specialist going around trying to teach science lessons from a cart. For a while, we actually turned our staff room into a science classroom. Now we have teachers that are gung-ho and they like science. It's not you know,

when you have a successful program; it's not just one thing. It's not just the principal. It's not just the teachers or one teacher, or not just the kids. It's like everyone. This is just really a unique environment.

The district to which Madison elementary school belongs does not have a policy regulating the minimum number of minutes of science instruction, nor does the school itself maintain a policy establishing science-teaching expectations. Yet, it appears that the culture of the school promotes an unwritten expectation to provide students science instruction. Take for example the way Peyton, fifth grade teacher and 26 year veteran, explains,

I'm not sure if we actually have policies about how much science we're supposed to teach. But, as a science magnet we'd want to do more anyway. We have our science specialist. So, we know that science is being taught in the lab. We [classroom teachers] should be doing the lessons, the exercises, the questions, discussing terms, and diagrams and tables. She [lab teacher] counts on what we're doing in our classrooms to reinforce the concepts so she can do hands-on labs.

As a way to further promote a STEM identity among students, all participants suggested that teachers had to also possess or acquire a STEM identity of their own. While some teachers acquired their STEM identity by working in a STEM-focused school, others had a strong STEM identity already intact prior to teaching at the school.

For example, Taylor expressed how her own STEM identity has been a motivating factor for her enthusiasm to teach science, “I like science. I was always interested in science. You have to like science and want to teach it. Not just because it’s a science school and it’s the rule.” On the other hand, Kennedy suggested that some teachers had to work to develop a STEM identity and how the lack of a STEM identity might harm student outcomes,

You can’t be like, ‘Oh my gosh! I hate science. Or, I am so technically challenged. Or, I hate math.’ You just can never do it. You have to love those things and be just (pause), be willing. Otherwise, you do a disservice. Like it’s unfair to your kids, you know what I mean? You rob them [students] of their future experiences when your anxiety starts to come out. Instead, confront your anxiety and you’ve made it a really exciting subject.

Some strategies used to nurture a STEM identity within students described by teachers were practiced school wide, like career days and science projects. In general, these activities are organized by school personnel for the benefit all students. Peyton described the benefits he believed career days offered students, “We want to make sure that kids are aware of science and how science plays a part in careers.” Another school-wide practice was the use of yearlong science projects. Every student takes part in an extended project focused on a grade level theme that is, “Related to their [grade-level] adopted curriculum and standards.” While discussing these yearlong science projects,

Ryan acknowledged the unique value these particular projects offer students, “They’ve [students] actually learned a lot over the year. It’s teaching them something that’s incredibly valuable that they don’t get somewhere else.”

Teachers were very explicit that these yearlong projects were not “science fair projects.” Several teachers believed that science fair projects completed at home might not be student work. Morgan shared her fear that traditional fair projects completed at home might have, “Too many parents overstep their role and do too much of the project.” She added, “I hate [traditional] science fair projects. Because the parents do beautiful projects.” Reagan explained that the yearlong projects are done at school, but science fair projects are done at home, “I don’t consider the yearlong project to be a science fair project. They are two different things to me.” Furthermore, as mentioned previously, engineering principles are not often explicitly taught in elementary school activities. However, engineering principles such as planning, creating, and improving design appear to be addressed in these yearlong projects. Reagan stated that students receive several benefits from participating in these yearlong projects, but particularly, “working over a long period of time on a project. As well as making mistakes and redesigning their experiments.”

Other STEM identity promoting strategies occurred at the classroom level, like guest speakers and fieldtrips. These practices were organized by classroom teachers and varied across grade levels. Sometimes these practices are simple. For example, during a

discussion about science teaching in her classroom, Kennedy referred to her students as “scientists.” When asked to explain why she does that she said, “Yes, we call each other scientists all the time. It’s always the case. You know, I call them scientists so they become scientists.” Other classroom practices were more complicated. Peyton described how difficult and time consuming it is to find people in STEM careers who are willing to come visit fifth grade students. However, he believed the benefits were well worth the time he had to invest,

We get outside people to come in and talk about it or we connect with companies. They become part of their [students] little world and they [students] see what they [guest speakers] did and how science is incorporated and how technology is incorporated. It’s really kind of using our own avenues. These are the connections; the bonds that we need to make.

Teachers also believed that STEM identities of students were strengthened when students have opportunities to engage in scientific discussions with adults other than teachers, particularly parents. These conversations were different than discussions where students collaborated to learn new information. Instead, these conversations were opportunities where students shared what they knew or what they were learning; these were opportunities to use their scientific knowledge to inform others. Take for example the way in which Casey described the school’s science and astronomy nights, “It’s the whole school. Families can come. We encourage everybody to come. It’s another

experience, a chance talk to someone else.” Reagan explained the relationship the school has with a local community organization that provides science experiences to schools and trains parent volunteers to deliver additional science lessons in classrooms. While these lessons support the yearlong science projects, they also provide students an additional opportunity to engage in scientific conversations with other adults,

The students also receive instruction on a monthly basis through our science docent program, where parent volunteers obtain training from the Math/Science Community Center (pseudonym) so they can deliver hands-on lessons in the docent lab. Students really have a great time in the docent lab because it’s a change of scenery from their usual work. But, the content is still aligned to their yearlong projects and the grade level curriculum. The happy side effect is that it encourages science conversations at home and these parents can see what their kids have done over the year.

While it is clear that teachers aim to promote STEM identities among all Madison students, they appear to be more intentional with those student populations generally underrepresented in STEM fields. Peyton recalls the transition to becoming a science magnet school, “We talked about how girls when they go into 7th and 8th grade or high school they drop when it comes to math and science. When we discussed why is that happening, I remember we were like, ‘Look at your own teaching and see what you’re doing. Are you guys doing anything that might start this?’” Madison teachers

appear to reflect on their own practice to explore subtle things that might perpetuate negative stereotypes and then identify ways in which they can intentionally combat such stereotypes. Peyton points out how this critical reflection has empowered the school to be more equitable,

Now the school as a whole believes, like the barriers are gone. We just treat everyone fairly and we want everyone to do well. We could care less if you're a girl or a boy, alien or whatever. We are very proud of the fact that girls are very involved in science. Hispanic kids are very involved in science and that's not typical out in the industry.

While talking about how important it is to support girls in science, Reagan shared a personal story that she says has influenced the way she supports underrepresented students in science today,

It was my 6th grade teacher who told me, 'You're really good at math. You might want to look into engineering.' That's something I've carried with me for the last 20 years. But, I was pushed out by a white man. I had a math teacher who told me I was stupid in front of the whole class. I was like, how is that possible when I have an A?

She went on to emotionally explain that she did not want that same experience to happen to other young girls, "But wow! I realize how much sexism has affected me. Now I try to do what I can, because I still hear it sometimes from girls. 'This is too hard. I can't do

this. I'm not good at this.' It's only from girls that I hear that. So, I am like, 'Yes, you can do this.'" Female teachers in particular felt a personal responsibility for combating stereotypes. Morgan simply stated, "I'm a girl and therefore a role model for girls."

Where as Kennedy explained, "Being a woman, I really try to reach out to all girls. Not that the boys aren't, but I feel that the girls need to be raised up. I feel like if they have that opportunity to excel in something that has been traditionally navigated by mostly boys and men. The girls just seem to be eager to do that."

This section described practices Madison teachers used to provide students experiences to "be STEM." These practices helped develop or promote students' STEM identities. In general, a STEM identity refers to the degree in which a student perceives him or herself as competent and confident in a STEM discipline (Paulger, 2015). These practices included the school's culture, teachers' STEM identity, school-wide experiences, classroom-based experiences, opportunities to engage in discussions with others, and specific strategies for support underrepresented students.

Supports and Resources: "Wanting More"

"The reality is that you're going to have to go get information because it just isn't going to come to you. We have to go get it. Be willing to just go! That's definitely something that's essential for this type of school."

-Kennedy (Kindergarten)

Table 10: Coding tally chart for areas in which teachers reported they wanted more. Each value represents the number of times the subtheme emerged during participant interview.

Pseudonym Grade	Wanting more			
	Communication and collaboration	Clear STEM vision	Professional development	Community involvement
Kennedy Kindergarten	13	9	10	2
Taylor 1	9	6	5	4
Casey 2	24	15	12	4
Ryan 4	6	6	3	10
Peyton 5	9	7	2	17
Reagan 6	8	20	5	9
Morgan Science Specialist	2	2	12	0

Teachers reported many supports and resources that facilitate teaching and learning of STEM content. These supports included a principal passionate about science teaching, parents willing to offer what ever the classroom needed, and connections to people with expertise in science content. However, what truly resonated throughout participants' conversations was the desire for more from their school. Although very

proud of their school and what it accomplishes, teachers felt that if they just had “a little more” it would be an even better and more effective learning environment. Table 10 shows the coding results in the form of coding tallies to demonstrate the extent to which participants expressed areas in which they wanted more.

Communication and collaboration emerged among all participants as something teachers wanted more. While all teachers indicated that communication and collaboration among colleagues at the same grade level is present and effective, many of them suggested they would like more opportunities to collaborate and communicate across grade levels and throughout the entire school site. Casey for example, reported communication as one of her more frustrating issues. She expressed her hope that communication would become a more open and welcomed practice, “I would like to have that open communication available and not to have approval all the time for every little conversation.” As an example of communication needs, she described how the abundant parent volunteers are valuable resources who want nothing more than to support the school. However, because of strained communication, they are sometimes unclear about how best to do so,

They [parents and volunteers] want to help and they are asking for help. I would definitely allow them to speak with the teachers. They’re asking for help and we want to help. But, we can’t really have that conversation. That conversation isn’t happening and I think it needs to. You know, to make it work.

Ryan described communication as a conflict. She wished communication would become a practice that did not make her feel like she was breaking the rules when she felt the need to talk with members of the school community. She reflected, “I respect people’s authority and of course if your boss says no conversation then that means no. People have their reasons. I’m not going to ask why. But, people want to talk.” She further suggested that this absence of collaboration and communication has been a significant challenge for her,

I think probably it’s the most difficult part—I would love to have a cohesive group of people to sit down and chat with and say, ‘Look this is what I’ve been struggling with. Can you help me?’ You know, more of a PLC [professional learning community] type of environment. Some grades are good about meeting. At my other school, I had people to bounce more things off of. So, that’s difficult sometimes.

When asked about the role that collaboration plays in STEM teaching and learning, Morgan indicated that it does not happen often enough across grade levels, “I don’t think that I have enough collaboration with each grade level. I think that is something that is much needed.” She went on to explain that she is willing to collaborate with her colleagues; it just is not made a priority, “I told them, please invite me and nobody has invited me.” Reagan recalled that when she was first hired she was excited at the prospect that communication and collaboration would be different than her previous

experience. She explained, “I kind of expected kindergarten to know what first was doing, and first would want to know what second was doing and there would be all this cross collaboration. You would think that.”

The desire for a stronger, clearer STEM vision was evident among all participants. This theme resonated the strongest with Casey and Reagan. These participants expressed frustration with doing more science as the largest reason for being a STEM school. Reagan, a sixth grade teacher, explained,

You’d think that with a science magnet they would know or have a better idea about what we’re doing. But, I’m still not entirely sure how this whole program works because there are so many different parts. I’m just hesitant to really claim we have a special program because I don’t know what the school’s vision and mission are I guess. You can’t just say we do more science and that’s it.

Casey described what makes her school different as a STEM school, she described disappointment because without a clear vision, the components are not connected and cohesive, “This is a great community, but as far as more science I don’t see it. I don’t hear it. It’s just a science magnet title. It’s kind of sad that I have nothing to compare to, no guidance. There’s just no connection.” Although Casey has taught elementary school for five years, recall that she is teaching second grade for the first time after returning from an extended absence. She was not teaching while Madison transitioned from simply a science magnet school to a broader STEM focus.

On this same topic, Kennedy suggested that having a clear vision would make it easier to describe to parents and others what it means to be a STEM school, “So a lot of people do ask, ‘What does it mean? Does it mean that you just do more science?’ I know it’s okay not to know, you don’t have to know everything.”

Ryan voiced her frustration this lack of vision causes her, “I just don’t know what it is. I almost get to the point where I wish people would stop saying STEM. Stop saying, ‘Oh, we’re STEM.’ If you’re going to be STEM then you need to be STEM.”

Professional development also emerged among all participants as a need.

Recall Kennedy for example, who spoke about calling her students scientists, the great collaboration among her grade level team, and how empowered the girls on campus were. She voiced disappointment that teachers had to seek professional development on their own to improve their content knowledge and teaching practice. She pointed out that to work in a school that focuses on STEM content, teachers could not just wait around for the site principal or school district to provide the professional growth necessary for improving practice. This belief resonated most when talking about implementation of the upcoming Next Generation Science Standards. She commented,

Right now, it’s [Next Generation Science Standards] just kind of an idea. Not much information has been given as far as what it looks like. It’s hard for people to visualize it on their own when you don’t have something physical. It’s a little

scary. We'll [grade level team] probably work on it during the summer so that we're ready.

Along this same vein, other teachers added that they too, wait for professional development that is very slow to materialize. Morgan commented on this trickling professional development, "The district has been doing a little bit more in the last couple years, especially with NGSS. But, if I want more I go on my own. I've gone on Saturdays or I go after school." Reagan also commented specifically on the absent science professional development, "There's not a whole lot. Right now, it's just a struggle with what model we are going to be going with NGSS. How is it going to work out? We have to keep waiting, because that's a lot of money. That's a lot of red tape." Clearly, professional development emerged as an area where teachers reported the desire for more. Recall that most (12 of 14 [86%]) of the Madison survey respondents indicated that inquiry-based professional development was very or fairly important, yet only a few (3 of 14 [21%]) felt inquiry-based techniques were actually emphasized during district or site-based professional development opportunities offered over the past three years.

A last topic of wanting more expressed by teachers was community connections. The school already has an established relationship with a nearby community center that provides the school with science curriculum, science classroom volunteers, resources, and professional development. However, teachers wished to access other community resources. Peyton believes businesses within the community

engaged in producing STEM related products could provide a valuable experience for students. He explains, “I think it’s really important that the kids be able to go into companies, businesses and see what science plays in all this. Like engineering. You know seeing all the engineering and all the science that takes place in a car being made or in another factory.” He adds that he is unsure about who at the school should be responsible for making these connections beyond the school, “I am not sure if it’s a science committee or principal or other leadership of the school. The missing link is the person or the committee or whatever. We need someone that helps facilitate those kinds of relationships beyond the classroom, beyond the school. But, we really should be getting out there and trying to get more.” Ryan echoed similar beliefs. She acknowledged the fruitful relationship with the nearby community center and desires more such relationships. Moreover, like Peyton, is unsure about who should be responsible for establishing such partnerships,

We have that partnership with the Community Center (pseudonym), which is excellent. We definitely need more, you know expert connections. Reaching out of the schools more. But you can’t spend your day running around. We need that kind of support to free up the stuff that I really want to spend time on.

Overall Summary of Survey and Qualitative Findings

This chapter presented the major findings uncovered by this study. Data from surveys and individual interviews revealed the complex nature of participants’ practice.

The findings reveal various practices and beliefs teachers at a STEM-focused elementary school might have about STEM teaching and learning. It offers explanations as to what these STEM-focused elementary schools teachers believe are important components of their practice.

Participants completed the Statewide Science Education Survey for Elementary School Teachers. These results were compared to the survey results of elementary school teachers across California. First, the survey findings revealed that participating teachers reported using hands-on practices more often than do California elementary school teachers in general. Furthermore, while participating teachers felt as prepared as other California teachers to integrate multiple school subjects, Madison teachers claimed to use integration more often. Additionally, teachers reported providing students more minutes of science instruction per week than California teachers. Additionally, while only 1.4% of California elementary school teachers hold a degree in a STEM discipline, more than one-third (5 of 14 [36%]) of participating Madison teachers reported holding an advanced degree in a STEM discipline. Lastly, while participating Madison teachers claimed to be as prepared to teach science as are California teachers in general, they reported feeling less prepared to teach English language arts, mathematics, and social science than their statewide counterparts.

The remaining major findings sprang from the qualitative in-depth interviews. These findings were reported in the qualitative findings section that began with a brief

profile of each interview participant. The first important qualitative finding was that all participating teachers valued using student-centered practices to deliver STEM content. These practices included hands-on experiences where students engaged in project-based learning. In addition to hands-on experiences, Madison teachers reported integrating multiple subjects to some degree as part of their regular practice. Likewise, teachers also reported providing students opportunities to make choices about when and what kind of content they wanted to study as well as offer students opportunities to collaborate with one another. An additional practice teachers indicated important in promoting STEM teaching and learning was providing students with learning experiences that occurred outside the regular classroom. Finally, participating teachers indicated that they avoided the teacher-centered practice of direct-instruction as it stood in contrast to their belief of providing students with active rather than passive learning experiences.

The second qualitative finding was that teacher participants expressed the importance of providing students with opportunities to cultivate a new or strengthen an existing STEM identity, opportunities to “be STEM.” STEM identity refers to the degree in which a student perceives him or herself as competent and confident in a STEM discipline (Paulger, 2015). Participants reported that STEM identity development first began with the culture of the school. Teachers suggested that having a strong STEM identity of their own further promoted or strengthened the STEM identity of students. Some school-wide strategies for promoting STEM identities among students included

career days and science projects. Other activities used by teachers to influence STEM identity occurred at the classroom level, like guest speakers and fieldtrips. Furthermore, teachers reported providing students opportunities to engage in scientific discussions with people other than teachers as a way to strengthen STEM identity. Lastly, while teachers reported the desire to promote STEM identities among all Madison students, they indicated they were more intentional in cultivating the STEM identity of those student populations typically underrepresented in STEM disciplines.

The third and final qualitative finding focused on the supports and resources participating teachers identified as “wanting more” of to further promote STEM teaching and learning. Teachers expressed a need for more clear and frequent communication and collaboration among all school stakeholders. Participants also reported a desire for the school to develop a more clear STEM vision. They believe having a clear vision would facilitate their own understanding of what it means to be a STEM-focused school. Furthermore, all teachers reported wanting more professional development. Teachers expressed disappointment waiting for development that will improve their practice and instead must seek their own development. Lastly, while the school enjoys a strong relationship with a nearby community center that provides curriculum support, teachers expressed wanting more such relationships. These teachers believe community businesses that specialize in STEM related products might provide students with valuable

learning experiences. Teachers admit that they are unsure who within the school ecology should be responsible for establishing such community connections.

Chapter Five: Discussion and Conclusions

There has been increased demand from supporters of STEM education to improve STEM outcomes by increasing the number of STEM-focused elementary schools available to students (PCAST, 2010; Judson, 2014). While there exists a body of empirical, peer reviewed literature examining the outcomes of STEM education at the secondary and post-secondary level (see for example: Erdogan & Stuessy, 2015; Hansen, 2014; Peters-Burton, Lynch, House, & Han, 2014), very little is known about the role elementary education plays in STEM outcomes. Additionally, there are so few elementary schools that explicitly embrace a STEM emphasis, claims about their potential are not yet supported with empirical evidence (Judson, 2014; Subotnik et al., 2010). This study sought to understand the practices and beliefs of teachers at one STEM-focused elementary school in order to provide insight about how to encourage and support other current and future institutions to successfully implement practices reported important in promoting STEM teaching and learning.

This study has filled an important gap in the literature regarding STEM-focused elementary schools. While literature does exist on the efficacy and components of STEM-focused high schools, very little research has been conducted examining the educational practices of STEM-focused elementary schools. It has been suggested that

educational practices may be among the most important criteria for determining the efficacy of STEM-focused schools (National Research Council, 2011).

This research used case study design to collect qualitative data by administering a survey, conducting in-depth interviews, and collecting supportive data through classroom observations. Fourteen teachers participated in the survey; seven of these teachers then participated in interviews; finally, four of the interview participants took part in classroom observations. Interview data were coded, analyzed, and organized by categories and subcategories using an emergent coding scheme. The study was based on the following three research questions:

1. How are practice, preparation, self-efficacy, and beliefs about teaching and learning of teachers at a STEM-focused elementary school similar to and different than a larger representative sample of elementary teachers in California?
2. What instructional practices do teachers at a STEM-focused elementary school report as important for promoting STEM learning?
3. What supports and resources do teachers at a STEM-focused elementary school identify as critical in developing and promoting STEM teaching and learning.

The previous chapter presented the findings of this study by consolidating the data into categories to produce a readable narrative. The purpose of this chapter is to provide

interpretations of these findings and demonstrate the implications and recommendations that then arise from them. While the previous chapter disaggregated pieces of the data to tell a story, this chapter is an attempt to reconstruct a more holistic appreciation of the information. The implications of these findings are meant to support the understanding of the practices valued by teachers at a STEM-focused elementary school.

What Makes this STEM-Focused Elementary School Different from Typical California Elementary Schools?

Student-centered learning environments that engage students in inquiry-based learning experiences are not typically found in elementary classrooms (Duschl et al., 2007). However, the majority of participating teachers indicated that although they feel similarly prepared as other California teachers to implement hands-on inquiry-based teaching practices, they actually use more of such practices more often than their statewide counterparts do. A conclusion to be drawn from this finding is that working in a school that has an explicit STEM emphasis may facilitate the use of inquiry-oriented teaching strategies and student-centered learning environments, even absent of specialized preparation to do so. Inquiry-based teaching practices have been reported to increase student engagement as well as improve learning outcomes (Dorph et al., 2011; Duschl et al., 2007; National Research Council, 2011; Sawada et al., 2002). Additionally, this finding supports the previous research of Peters-Burton, Lynch,

Behrend, and Means (2014) who have posited that inquiry-based teaching practices are possibly among the most critical components of STEM-focused high schools.

Teacher participants believed that hands-on is what constitutes “real science” and being actively engaged was the best way for students to learn STEM concepts. Participants described using inquiry-based strategies to provide students opportunities to actively engage in STEM content though there existed no school policy or explicit expectation to do so. On the contrary, participants expressed frustration that the professional development offered by school leaders has failed to meet their needs or desire for increasing their efficacy to implement inquiry-oriented teaching practices.

As additional evidence for valuing inquiry-based rather than teacher-centered learning environments, nearly every Madison reported avoiding using direction instruction as their main strategy for teaching content to students. Teachers recalled how direct instruction was the primary strategy for learning content when they were students and have made conscious efforts to provide students with active learning experiences instead. Furthermore, direct instruction does not fit these teachers’ interpretation of what constitutes “real-science.” Teachers pointed out that learners are not given all the necessary information when solving problems or designing solutions. Instead, real-world problem solving involves a degree of sleuthing, investigating, and experimenting, characteristics ideally situated in active learning strategies found in student-centered learning environments (Duschl et al., 2007). However, the avoidance of direction

instruction did not mean the absence of teacher support. Rather, in line with the previous findings of Blanchard et al. (2010), participating teachers engaged students in levels of inquiry by providing guided instruction through the use of strategies such as facilitating, questioning, or guiding to provide students the necessary supports to be successful in learning content.

While the average California grade K-3 classroom offered only 19 minutes and grades 4-6 offered only 24 minutes of weekly science instruction (Banilower et al., 2013), the majority of Madison teachers at all grade levels reported providing at least 120 minutes per week of science instruction to students. Furthermore, Madison teachers have committed to teaching more instructional minutes in science without a specific school policy dictating a required minimum number of science instructional minutes. A conclusion that can be drawn from this finding is that simply designating the school a “STEM school” may result in teachers committing to teach more science than what is typically delivered by California elementary school teachers in general. One explanation for how Madison teachers are able to offer more instructional minutes in science is their content integration.

Integration as a strategy for increasing the number of instructional minutes in content areas, particularly science, is supported by current research (Dorph et al., 2011). Although Madison teachers reported feeling as equally unprepared to integrate science content with other subject areas as other California elementary teachers, nearly every

Madison teacher reported often or always integrating science with other subjects as part of their regular classroom practice. The teachers also indicated that they are offered too little support increasing their capacity to integrate science into other content areas. A conclusion that can be drawn from this finding is that having a STEM designation may result in teachers committing to use practices that facilitate increased instructional minutes in science above the California average even though they lack preparation and are not mandated by clear school policy to do so.

A third difference between Madison teachers and California teachers in general was that Madison surveyed teachers reported holding advanced degrees in science more than the California average. In general, most elementary school teachers do not have undergraduate or graduate majors, minors, or concentrations in STEM disciplines (Banilower et al., 2013; Dorph et al., 2011). For example, only 1.4% of California elementary school teachers hold a bachelor's degree or higher in a science discipline (Dorph et al., 2011). Yet, more than 30% of Madison surveyed teachers and nearly 30% of interviewed teachers claimed to hold an advanced degree in a science discipline. Whereas prior discussions of preparedness were in regards to teaching strategies, this finding suggests that some Madison teachers are better prepared in science content knowledge than the majority of California elementary teachers. A conclusion that can be drawn from this finding is that teachers with advanced science content knowledge may be attracted to working in an elementary school with a STEM emphasis as to promote

increased science foundational skills among primary aged children. For example, two Madison participants reported holding high school science teaching credentials and had previously taught high school. These two teachers expressed their desire to work at the elementary level where they believed science was neglected, partly because they believed elementary teachers are, for the most part, improperly prepared to teach science effectively. Kennedy, a kindergarten teacher, explained her motivation for moving from teaching high school to teaching elementary school,

That's partly the reason why I wanted to come to elementary, because I was aware of that. I saw it when I was student teaching. I saw it when I went to all my professional development sessions. There are elementary teachers who just maybe don't understand or are afraid of science. My husband even told me...he thinks that I can do a lot more helping elementary.

A fourth difference between Madison teachers and California teachers in general is that Madison teachers reported feeling less prepared to as prepared to teach English language arts, mathematics, and history, although they claim to feel as prepared to teach science as other California teachers. A conclusion that can be drawn from this finding is that maintaining a curricular focus on science has led to a reduction of emphasis on other content areas. Other research has indicated a similar effect on science instructional minutes in schools that have increased attention on language arts and mathematics (Banilower et al., 2013; Dorph et al., 2011; Duschl et al., 2007; Judson, 2013). If the

Madison teachers provide their students with more instructional minutes in science than is typical in the average California elementary school classroom. When asked what makes their school different, Madison participants consistently stated that they provide more science than do other elementary schools. They claim that the school has no policy mandating the kind or amount of science students' should be receiving. Instead, teachers point to the simple fact that, "every class does science because it's expected. If classes aren't doing it, it's really noticeable because everybody around them does it and so if they think that they can skip out of something, they kind of have this campus wide pressure to do it."

Leadership Challenges in this STEM-Focused Elementary School

While many practices involved in educating children focus on the pedagogical decision making processes of teachers at the classroom level (Rubie-Davies, 2012), others move beyond the classroom to include the entire school community. It is important for school leaders, be those principals or teacher leaders, to know and understand the needs and wants of actors within the school ecology framework, particularly those needs expressed by teachers for improving practice. The findings from this study revealed that participants sought support from leadership in a variety of areas. First, they indicated wanting support in promoting the STEM identities of students by facilitating a school wide culture that promoted STEM. Second, teachers wanted support in strengthening their own STEM competence and identity. Lastly, teachers wanted a

school has maintained a focus on science content areas through the encouragement of science instruction and the provision of science professional development at the expense of other academic areas, one could hypothesize that confidence in other content areas might weaken. Teacher beliefs and confidence have been shown to play a significant role in the decisions teachers make about curriculum and pedagogy (Pajares, 1992; Rubie-Davies, 2012; Wheatley, 2002).

In summary, STEM supporters have expressed concern that schools wishing to become STEM- focused schools will simply adopt a STEM moniker. Proponents of STEM education fear that schools will take on a STEM name, yet have nothing within the school ecology that distinguishes the school as significantly different than a school without STEM designation or better serving of STEM teaching and learning goals (Bybee, 2010). However, evidence from this study suggests the contrary. Evidence gained in this study suggests that calling the school “STEM-focused” may be enough to promote a school wide culture that encourages behaviors that have been identified as potentially critical to STEM teaching and learning (Means, Confrey, House, & Bhanot, 2008; Peters-Burton, Lynch, Behrend, & Means, 2014). Madison teachers claimed to feel no more prepared to implement these components than other California teachers, yet they implement and use more of these strategies more often than do other California elementary school teachers. Madison teachers claim to feel underprepared and under supported by school leadership to integrate multiple content areas together. However,

school wide focus and commitment in providing intentional support for students traditionally underrepresented in STEM disciplines.

A STEM-identity refers to the degree in which a student perceives him or herself as competent and confident in a STEM discipline (Paulger, 2015), in essence, their “STEMness.” As part of the school’s ecological structure (Erdogan & Stuessy, 2015), the culture of a school influences the experience of all those involved in the school context. For example, as mentioned previously, Madison maintains no policy regulating the number of instructional minutes in science. Yet, classroom teachers provided students instructional minutes in science greater than the California average. The district to which Madison belongs does not have a policy regulating the minimum number of minutes of science instruction, nor does the school itself maintain a policy establishing science-teaching expectation. Instead, teachers pointed to the overall culture of the school as the facilitator for promoting science instruction.

Participants believed that being a STEM school should not simply mean doing more science. Instead, teachers described wanting “a better idea about what we’re doing.” Teachers believed a strong and clear vision would strengthen the school by ensuring the various initiatives across the entire school were cohesive and supportive of one another by connecting them to a central vision or belief. Previous research supports this finding and suggests that school culture may do more to promote or hinder STEM outcomes than even teacher qualifications (National Research Council, 2011).

Participants reported struggling to understand what it really means to be a STEM school. Teachers added that a clear STEM vision would help them explain to parents and other community members what the school is really about.

An additional support expressed by participants as needing leadership attention was community connections. Connecting to the community beyond the school was seen by participants as a possible way to expand STEM resources. Leveraging partnerships with external organizations such as businesses, colleges, universities, technical schools, and museums has the potential for increasing student engagement and outcomes (Means, et al., 2008). The school already partners with a community STEM center that provides lessons, guidance, and training for parent volunteers to deliver science lessons to students in classrooms. Teachers expressed an interest in expanding on this idea by including other organizations that would supplement STEM teaching and learning. For example, Peyton, a fifth grade teacher, believed that making connections with businesses within the community that engaged in the production of STEM related products could provide students an avenue for real-world experiences. Other participants shared Peyton's enthusiasm and believed that if connections and relationships were cultivated properly and respectfully, the community could essentially become an extension of the classroom for providing STEM teaching and learning opportunities. However, teachers were at a loss for how to make these connections on their own without school leadership support and guidance.

Evidence from participants also revealed that to promote and strengthen the STEM identity of students, teachers should have or be developing their own STEM identity. Similar to other research, Madison teachers described how their own confidence motivated them to teach STEM content (Gibson & Dembo, 1984; Mansour, 2010; Rubie-Davies, 2012). Some teachers had a fully developed sense of themselves as “doers of science.” One teacher explained, “I like science. I was always interested in science. You have to like science and want to teach it.” Although it appeared that a teacher’s STEM identity was not required be fully developed, it was expressed that teachers should be working to strengthen their existing STEM confidence. Take for example the way one teacher described the concept of developing science teaching confidence, “You can’t be like, ‘Oh my gosh! I hate science. Or, I am so technically challenged. Or, I hate math.’ You just can never do that. You have to love those things and be just, be willing.”

Among the most talked about supports for promoting STEM identity among teachers were communication and collaboration. Although communication and collaboration are two very distinct practices, participants discussed them as if inseparable or interchangeable. While participants acknowledged that teachers at the same grade level often engaged in communication and collaborative work, missing from the school setting was communication and collaboration among other actors within the school context. Teachers expressed concern and frustration in school leadership for not fostering and facilitating productive dialogue among school stakeholders. For example,

teachers wished they had opportunities to talk with the parents who volunteered in the school as science docents. They described these volunteers as abundant resources who were willing to help but did not always know what to do to be the most help. Teachers explained the importance of these volunteer parents coming to understand more about the lessons they as docents bring to classrooms, and how such lessons fit within broader units of study within each classroom. They explained that having opportunities to engage in dialogue with these volunteers would help to better align the docent program to support classroom instruction. Another example offered by participants about the need for collaboration was with teacher teams from different grade levels, often referred to as vertical collaboration. The recent work of Behrend et al. (2014) highlighted vertical collaboration as an important component of successful STEM high schools. Teachers described the various school initiatives as pockets of “really great” things happening among different community members across the campus but with no established methods for communicating, it was difficult to share best practices or learn from one another. Open communication and collaboration were believed to be a vehicle for all school members to share best practices, get feedback for improving their practice, and in general, increase moral among school personnel and improve outcomes among students.

As mentioned previously, participants valued student-centered learning environments that used reformed-based teaching practices to engage students in learning STEM content. In light of this value, it is not surprising that participants would cite their

desire for more professional development in learning how to implement such teaching strategies. Furthermore, participants explained that not only have very few of them had professional development in STEM content during the past five years, but also they felt that no school leaders direct them to appropriate professional development. Teachers cited this lack of adequate guidance as the impetus for identifying and locating professional development activities they believed would supplement or increase their effectiveness in creating student-centered learning environments.

Furthermore, this lack of adequate professional development support may explain why some teachers expressed difficulty implementing reformed-based teaching practices, though knowing such practices are proven to promote improved student outcomes (Colburn, 2006; Duschl et al., 2007; Sawada et al., 2002). Take for example the words of Casey as she discussed this disconnect between what she believes is the right way to teach science and the way she feels it actually gets addressed in her classroom. First she explained her beliefs about science teaching, “I think with science it needs to be hands-on...It’s important that it be hands-on...because if you’re going to lecture the whole time, you’re going to lose 99%, 100% of these kids. What are some things we can bring in to our lessons and really make it even more interesting for kids!” Then went on to describe her actual science teaching, “When I teach science, sadly it’s just okay. It’s just here’s our textbook. We’re going to do vocabulary. Here’s the vocabulary. Let’s talk about it. Here’s your science homework; take your books home and bring it back when you’re

done. That's how it is. That's how my science lessons are. Sad isn't it!" Casey then pointed out her desire for school leadership to aid in alleviating this disconnect between belief and practice, "It would be nice to have some support from the district you know. Just to say, 'Hey, these are some resources you can use and you can integrate this along with your-you know, you can mix it in with your language arts and also math.' It would be nice to have that available and to show us how to use it. It just feels like it's not there."

Current research regarding minority students' success and persistence in STEM disciplines highlights the need to increase their sense of belonging and engagement through support systems provided by the education institution (Museus & Liverman, 2010). Madison teachers explained that during the transition from a general elementary school to a science magnet and then more recently into a STEM-focused school, they were acutely aware of the fact that some populations of students were pushed out of the STEM circuit (National Science Foundation, 2013; Scott, 2010). Teachers recalled conversations they had about how to support these underrepresented students. They engaged in conversations and reflected on their practices trying to uncover specific behaviors teachers might be doing that covertly worked to discourage certain students from engaging in STEM disciplines.

However, dialogue about the intentional support of underrepresented students as a school wide focus has since ceased. Instead, teachers individually recognize the

continuing need to provide support for those students who might otherwise be discouraged from participating in STEM disciplines. For example, sixth grade teacher Reagan explained, “It’s not school wide. I have to do it in my classroom.” Several participants expressed a desire for stronger leadership on this topic. Teachers could not point to specific reasons for why concern for these students stopped being a school wide focus. They did however, express a desire for school leadership to make the support of underrepresented students a priority and involve the whole school community in conversations about better supporting students who generally get pushed out of STEM disciplines.

In summary, teachers identified several supports that they believed were important to the context of teaching and learning in a STEM-focused elementary school, but were missing from the school ecology and should therefore be addressed by school leadership. First, they reported the need for support using practices that would promote STEM identities among students as well as themselves. Teachers described the value they perceived the school culture contributed to the development of students’ STEM identities. Participants believed that a more pervasive STEM culture would provide a common thread for connecting initiatives across the school as well as communicating the mission and goals of the school to the community. Teachers also indicated a desire for improved connections to the community beyond the school. Teachers expressed a belief that connecting with STEM businesses would provide students with real-world

experiences in STEM disciplines. Participants also highlighted communication and collaboration among and between all members of the school community as an area of concern for leadership. Then teachers described the need for school leadership to support professional development initiatives that would increase teacher capacity for implementing inquiry-based teaching strategies. It was believed that professional development could help align teachers' beliefs about effective teaching and learning practices with their actual implementation of such practices in the classroom. Lastly, teachers described a desire for school leadership to make supporting students who are generally discouraged from participating in the STEM circuit a school wide priority.

STEM-Focused Leadership Recommendations

An important question following the findings of this study would be what actions and steps should Madison leadership take to promote the practices teachers reported as important to STEM teaching and learning. Following are several recommendations for school leadership. These recommendations are intended to promote those practices teachers identified as important in STEM teaching and learning.

Recommendation #1: Reform Instructional Strategies: Professional development to support teachers in utilizing a range of student-centered inquiry-based teaching practices

Provide teachers ongoing professional development opportunities that supports their own learning, promotes their capacity to implement inquiry-oriented teaching

strategies, and engages teachers in determining the professional development they need to become more effective at STEM teaching and learning. Teachers expressed a desire to teach using student-centered inquiry-based teaching strategies. These strategies included among other things, hands-on project-based activities, designing experiments, student collaboration, and integrating content. They described believing these types of practices as “real science” and the best way to learn science. However, teachers also indicated that professional development to strengthen the use of such practices was lacking.

Furthermore, they indicated that they wanted professional development experiences that focused on the actual content taught at their respective grade level, not an activity they had to adapt to meet the needs of a different grade level. Therefore, professional development should a) first assess the needs and wants of teachers; b) focus on the STEM content that is taught in the classroom using materials readily available; c) include opportunities for teachers to learn the STEM content they will actually be teaching at their grade levels; d) help teachers to understand changes in expectations arising from the new standards; and e) include opportunities for teachers to understand how students learn STEM content. Strengthening teachers’ confidence in implementing these student-centered practices would improve student engagement and outcomes by increasing the efficacy and overall comfort with inquiry-based teaching practices.

Recommendation #2: Inclusive STEM Mission: Develop a clear STEM vision for the school

School leaders should craft a clear STEM vision for the school. Creation of this vision should be in collaboration with all school stakeholders. Participating teachers indicated that they wished the school had a clear and strong statement of its STEM vision. Teachers felt this vision would then become the backbone of all the decision-making throughout the school that provided a common thread for all the various school wide initiatives. Teachers felt that a clear STEM vision would make it easier to communicate to parents and other community members what the school stood for and precisely what the school was trying to accomplish.

Recommendation #3: Real-World STEM Partnerships: Create a community partnership coordinator position

School leadership should find the resources to create a position of Community Partnership Coordinator. In collaboration with stakeholders, school leadership can create the specific roles and responsibilities for this position. However, two important functions this position will serve are: a) develop and expand partnerships with community organizations, and b) enhance student engagement in STEM disciplines through community relationships. In other words, the primary responsibilities of this position are to identify and forge potential relationships with community organizations that will facilitate STEM interest and engagement among students.

Recommendation #4: Well-Prepared STEM Teaching Staff: Recruit teachers who are knowledgeable in STEM content and pedagogy

Allow school administrator greater autonomy in selecting and hiring teachers with STEM credentials or experience, teaching philosophies that are aligned with the school mission and vision, and who have a willingness to work collaboratively. Recruiting highly qualified teachers has been a topic of conversation in public education for some time. STEM-focused schools have the added difficulty of finding teachers not only qualified to teach the general education requirements of elementary school, but also committed to promoting STEM teaching and learning. Continuing to hire teachers with appropriate STEM credentials or experience or facilitating the acquisition of such credentials or experience for in-service teachers will continue to strengthen the outcomes and experiences of students in STEM disciplines.

Recommendation #5: Administrative Structure: Promote a culture of collaboration and communication

Put into place structures and processes for open lines of communication among all school stakeholder and provide teachers with training on collaborative practices such as Professional Learning Communities. Participating teachers described their desire for better communication and collaboration among all school stakeholders. While structures are present for teachers to talk and work with colleagues at the same grade level, participants described feeling frustrated that similar processes were not in place to

communicate and collaborate with other members of the school organization. For example, the school has a close relationship with a community organization that provides curriculum and training for parent volunteer science docents. However, teachers have no process for working with the parent volunteers to strengthen or make more relevant to the classroom the lessons the docents deliver to students. Furthermore, teachers wished to communicate and collaborate across grade levels in vertical alignment, but the school lacked the culture and structures for promoting collaboration in this manner. Teachers hoped that such practices will allow for greater cohesiveness of STEM teaching and learning goals, including sharing of best practices.

Limitations

The process of analyzing the findings was to produce a holistic and integrated synthesis. The challenge throughout the iterative process of data collection and analysis was to find sense in large amounts of data, reduce the volume of information, identify significant patterns, and deliver an essence of what the data revealed as related to the purpose of the study.

The analysis of the findings uncovered in this study merits a degree of caution. First, the sample was small, comprising survey data from 14 teachers and interview data from only seven interviews. Second, the interview participants were selected upon the recommendation of the school site principal. Therefore, the participants might be more heavy adopters or implementers of the practices described here. Thus, the practices of

those teachers who have not adopted such practices to the same degree might not be represented. For these reasons, it must be pointed out that the implications that can be drawn are specific to the experiences of the sample group of teachers involved in this study.

Aside from the possible biases involved in researcher-as-instrument, as is typical of qualitative research, it is acknowledged that there is the possibility of additional bias in analyzing the findings because the researcher is also an elementary school teacher. To help minimize this limitation, throughout the data collection and analysis process, the researcher engaged in ongoing critical reflection through journaling and discussions with critical colleagues. Remaining open to the possibility that others may present a different story, this chapter is essentially, and ultimately, a presentation of how this researcher understands and interprets the meaning of the data collected.

Recommendations for Further Study

This study is unique from past research on STEM-focused schools because it does not overly rely on data collected from surveys administered to STEM school administrators (Brody, 2006). Instead, this study used qualitative in-depth interviews to examine the practices STEM-focused elementary school teachers reported as important in STEM teaching and learning. Future research is needed to examine the effects on student outcomes both short and long term. More research is needed to determine if attending a STEM-focused elementary school increases STEM aptitude and success. Furthermore, it

would be beneficial knowing if and how STEM-focused schools promote, constrain, or make no difference in students' persistence through the STEM circuit from elementary school to secondary and even postsecondary school.

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APPENDICES

APPENDIX A

TEACHER E-MAIL REQUEST FOR PARTICIPATION

Dear Teacher:

The purpose of this email is to request your participation in a study of STEM-focused elementary school teachers. This study is intended to identify components that teachers at a STEM-focused elementary school report as important for promoting STEM teaching and learning. The project title is "A Case Study Investigation of Practices and Beliefs of Teachers at a STEM-Focused Elementary School."

You have been chosen to participate because you teach at an elementary school identified as a STEM school. If you choose to participate, your name, the name of your school, and the names of colleagues will be replaced with pseudonyms. After your information is summarized, you will receive a preliminary copy of the data to confirm the accuracy of the information.

I am requesting approximately 45 minutes of your time to participate in an interview. When the information from the interview has been collected, a "Summary of Findings" document will be sent to you for your review. A follow-up telephone interview may be conducted to verify the accuracy of the information and add any missing information. I will also be asking you to participate in an electronic survey that will take approximately 20 minutes to complete.

If you are willing to share your experiences participating in a STEM school, please respond to this email with your contact information. Once received, I will contact you to schedule the interview at a time and location of your convenience. Your participation in this study is voluntary, but very important and greatly appreciated.

This research is being conducted by Billy Martin, Graduate School of Education at San Francisco State University. He can be reached at 408.402.2261 or bjmartin@mail.sfsu.edu for questions or to report a research-related problem. Faculty Supervisor is Dr. Stephanie Sisk-Hilton. Dr. Sisk-Hilton can be reached via email at stephsh@sfsu.edu

Thank you for your time and consideration,

Billy Martin

APPENDIX B

LETTER OF INFORMED CONSENT

San Francisco State University

A Case Study Investigation of Practices and Beliefs of Teachers at a STEM-Focused Elementary School

A. PURPOSE AND BACKGROUND

The purpose of this research is to: *investigate the practices and beliefs of STEM-focused elementary school teachers.*

The researcher, Billy Martin, is a graduate student at San Francisco State University conducting research for completing the degree of Ed.D in Educational Leadership. You are being asked to participate in this study because you are a teacher in a STEM elementary school.

B. PROCEDURES

If you agree to participate in this research, the following will occur:

- you will participate in an online survey that takes approximately 20 minutes to complete.
- you will be interviewed for approximately 45 minutes one time.
- the interview will be audio recorded to ensure accuracy in reporting your statements.
- the interview will take place at a time and location convenient to you.
- the researcher will provide you a “summary of findings” memo to verify the accuracy of your statements.
- you may participate in a 30 minute follow-up interview to add new information or clarify previously submitted information.
- the total time commitment is approximately 90 minutes.

C. RISKS

There is a risk of loss of privacy. Only the researcher will have access to the research data that contains identifying information. However, no names or identities will be used in any reports of the research, as all identifying information will be replaced with pseudonyms after collection

D. CONFIDENTIALITY

To reduce the risk of loss of privacy, all identifying information will be replaced with pseudonyms after collection. The identifying data will be kept separate, in a secure location, and only the researcher will have access to the data. All research data will be stored in an encrypted document on a password-protected computer. Audio recordings will be destroyed at the conclusion of the research.

E. DIRECT BENEFITS

There will be no direct benefits to the participant.

F. COSTS

There will be no cost to you for participating in this research.

G. COMPENSATION

Survey participants will receive a \$25 Amazon Gift Card as compensation for time. Interview participants will receive no compensation.

H. ALTERNATIVES

The alternative is not to participate in the research.

I. QUESTIONS

You have spoken with Billy Martin about this study and have had your questions answered. If you have any further questions about the study, you may contact the researcher by email at bjmartin@mail.sfsu.edu or you may contact the researcher's advisor, Professor Stephanie Sisk-Hilton at stephsh@sfsu.edu

Questions about your rights as a study participant, or comments or complaints about the study, may also be addressed to the Human and Animal Protections at 415.338.1093 or .

J. CONSENT

You have been given a copy of this consent form to keep.

PARTICIPATION IN THIS RESEARCH IS VOLUNTARY. You are free to decline to participate in this research, or to withdraw your participation at any point, without penalty. Your decision whether or not to participate in this research will have no influence on your present or future status at San Francisco State University.

Signature _____

Date: _____

Research Participant

Signature _____

Date: _____

Researcher

APPENDIX C

PRINCIPAL E-MAIL REQUEST FOR PARTICIPATION

Dear Principal:

My name is Billy Martin. I am a 5th grade teacher in Los Gatos, California and a graduate student at San Francisco State University. The purpose of this email is to inquiry about the participation of your school in a study examining the characteristics of teachers at STEM-focused elementary schools. This study is intended to identify common teaching practices and beliefs among successful STEM elementary schools. The project title is "A Case Study Investigation of Practices and Beliefs of Teachers at a STEM Elementary School."

I am interested in your school because of your commitment to increase content knowledge in STEM subjects for all students. If you choose to grant permission for your school to participate, the name of your school and the names of any participating staff members will be replaced with pseudonyms. At the conclusion of this study, you will receive a summary report of findings.

This study has been designed to avoid intrusions on the instructional day and to place minimal burden on school staff. In addition, no data will be collected from students.

I am requesting permission to contact your teaching staff via email to inform them of the purpose of the study and invite them to participate in an online survey. This study will be conducted during the fall and winter of the 2015-2016 school year.

Your participation is voluntary, but very important and greatly appreciated.

I look forward to hearing back from you regarding the possibility of your school participating in this research project. Thank you for your time and consideration.

Billy Martin

This research is being conducted by Billy Martin, Graduate School of Education at San Francisco State University. He can be reached at 408.402.2261 or bjmartin@mail.sfsu.edu for questions or to report a research-related problem. Faculty Supervisor is Dr. Stephanie Sisk-Hilton. Dr. Sisk-Hilton can be reached via email at stephsh@sfsu.edu

APPENDIX D

STEM EDUCATION SURVEY FOR ELEMENTARY SCHOOL TEACHERS

1. I'd like to start by asking about your opinions of science in schools.

Please tell us how important you think it is for California public schools to give all students a strong background in each of the following areas:

	Essential	Very important	Somewhat important	Just a little bit	Not at all important
Math					
History and social studies					
Reading and writing					
Foreign language					
Science					
Computer skills					
Art and music					
Nutrition and health					

2. In what grade do you think schools should begin to teach science?

Kindergarten

1st grade

2nd grade

3rd grade

4th grade

5th grade

6th grade

7th grade

8th grade

9th grade

10th grade

3. Which grade(s) do you teach? (Mark all that apply)

Kindergarten

1st grade

2nd grade

3rd grade

4th grade

5th grade

6th grade

7th grade

8th grade

4. Science can be taught in many different ways. In what ways do your students receive science instruction? (Mark all that apply.)

-Students receive instruction from a resource teacher who only teaches science.

-As a self-contained classroom teacher, I teach science to my students.

-Students receive instruction from more than 1 teacher who "team teach" science (possibly in conjunction with other subjects).

-Students receive instruction from another teacher who "specializes in science".

-Students go to a science lab to receive science instruction.

-Students receive instruction from volunteers or staff of community-based organizations.

-Science is embedded within Language Arts or other non-science academic area.

-A pacing guide is used to determine when to teach science and/or what content to teach.

-Other (please describe)

5. How many days a week do your students receive science education? Indicate the number of days that they receive instruction from you, from a resource teacher, or from another person.

	0 days	1 day	2 days	3 days	4 days	5 days	I don't know
--	--------	-------	--------	--------	--------	--------	--------------

Instruction from me							
Instruction from a resource teacher							
Instruction from another person							

6. How many minutes a week do your students receive science instruction? Indicate number of minutes that you provide instruction, that a resource specialist provides instruction, and that someone else (a volunteer, another teacher, etc.) provides instruction.

_____ Science instruction from me
 _____ Science instruction from a resource specialist
 _____ Science instruction from another person
 _____ Total

7. During the course of a school year, what percentage of the time is devoted to instruction in these different content areas?

_____ Life Science/Biology
 _____ Physical Science
 _____ Earth/Space Science
 _____ Other (please explain)

_____ Total

8. How often do you ask your students to do each of the following in your science instruction? Some of the items may not be appropriate for all grade level (e.g., Kindergartners are probably not writing reports), but please just answer each question as accurately as possible.

	Never	Rarely	Sometimes	Often	All or
--	-------	--------	-----------	-------	--------

					almost every science lesson
Listen and take notes during presentation by teacher					
Watch a science demonstration					
Work in groups					
Read from a science text book in class					
Read other (non-textbook) science-related material in class					
Do hands on or laboratory science activities or investigations					
Design or implement their own investigation					
Participate in field work (e.g., take water samples from					

local river)					
Answer textbook or worksheet questions					
Record, represent, or analyze data					
Write reflections (e.g., in a journal)					
Prepare written science reports					
Make presentations to the rest of the class					
Take field trips					
Watch audiovisual presentations (e.g., videotapes, CD- ROMs, videodiscs, television programs, films,					

or filmstrips)					
Integrate science with another discipline, such as math					

9. Do you personally receive direct support from a science resource teacher or instructional specialist?

☐ Yes

☐ No

What sort of support does the resource teacher provide to you?

☐ Coaches me on science instruction

☐ Team teaches science with me in my classroom

☐ Provides demonstrations of lessons to me (either individually or in a group of other teachers)

☐ Other (please describe)

10. Have there been any significant science education initiatives (e.g., special program, focus or attention on science) at your school in the past 5 years? (Mark all that apply.)

☐ No initiatives

☐ Statewide initiative (e.g., California Math-Science Project; please describe)

☐ Initiative with local science center (please describe)

☐ District-developed initiative (please describe)

☐ Other (please describe)

11. Does your school use kit-based curricula for teaching science?

☐ Yes

☐ No

Within your school or district, is there a system in place to replenish your kit materials?

☐ Yes

☐ No

☐ I don't know

Is materials replacement a barrier to teaching science in your classroom?

☐ Yes, a major barrier

☐ Yes, but a small barrier

☐ No, it is not a barrier

☐ I don't know

13. How well prepared do you feel to accomplish the following in your science teaching?

	Very well prepared	Fairly well prepared	Somewhat prepared	Not adequately prepared	
Use inquiry/investigation- oriented teaching strategies					
Use assessment tools to assess student learning in science					
Use technology to enhance science instruction					
Teach science to a class that includes					

students who have special needs					
Teach science to a class that includes students who are English language learners					
Integrate science content to support reading and/or math proficiency					
Use kit-based science curriculum					
Align science curriculum to California Science Standards					

12. Many teachers feel better prepared to teach some subject areas than others. How prepared do you feel to teach each of the following subjects at the grade level(s) you teach, whether or not they are currently included in your curriculum?

	Very well prepared	Fairly well prepared	Somewhat prepared	Not adequately prepared	
Reading/Language					

Arts					
Mathematics					
Social Science					
Life Science/Biology					
Earth/Space Science					
Physical Science					

14. Please tell us about the science-related professional development you have received in the last three years. How many hours have you received from each type of provider? If a training was given by a partnership of multiple providers, please select one response only. And, if applicable, please rate the quality of your PD experience.

	0 days	1 day	2 days	3 days	4 days	5 days	I don't know
County Office							
District office							
Informal learning institution							
Local community based organization							
Site-based							
Institute of higher							

education (college or university)							
Other (please describe)							

APPENDIX E

TEACHER INTERVIEW PROTOCOL

Demographic/Introductory Questions

How long have you been teaching?

What grades have you taught?

Have you taught in a state other than California?

Interviewer Introduction: Now I am going to ask some questions that are specific to science, technology, engineering, and mathematics education:

Beliefs

In what ways do you believe this school is different than other schools?

Describe the kind of student you feel benefits from attending a STEM-focused school.

How would you describe benefits students receive by attending this school?

Follow-up: Do you feel these benefits exist at other schools?

In your opinion, what is the most difficult thing about teaching at a STEM-focused school?

What age/grade do you believe is appropriate for students to begin learning STEM content?

How confident do you feel to teach STEM content at your grade level?

Follow-up: Has this been pretty consistent across your career, or has it changed over time?

Can you tell me more about that?

Do you believe that STEM education is appropriate for all students?

Preparation

What led you to teach at this particular school?

Can you tell me about your initial teaching preparation, and about experiences that have helped shape your teaching practice more recently?

Follow-up:

-What was the length of this preparation/these experiences?

-In what ways was the content delivered?

- Can you describe why these particularly experiences were so powerful in shaping your teaching practice?
- In what ways did these experiences change your practice?

What kind of professional development would you like to participate in that would strengthen your teaching in STEM areas?

What advice would you give to a teacher new to teaching STEM concepts or new to a STEM school?

Practices

How many lessons do you teach science, technology, or engineering per week?

Follow-up: How many minutes do you spend per week?

How do you decide which curriculum or curriculum resources to use to teach STEM content?

Could you describe a typical science or engineering unit and how you teach it? You might think of a recent unit you've taught. I'm interested in the kinds of activities and practices you think are most important to support children learning science and/or engineering.

Follow-up: If an observer came into your classroom during a science lesson, what would they likely see?

Has the way you teach science and engineering changed over time?

Follow-up: Can you describe how it has changed?

What key practices have stayed the same over time?

Are there new teaching methods that you would like to add or do more in your science and engineering lessons? If so, what are these, and why do you think they are important?

Are there ways of teaching science and engineering that you try to avoid or think are not effective? Can you explain why you feel these methods are not effective?

Support

What kinds of supports for STEM teaching are most important to your success with students?

Follow-up: What kinds of supports, if any, does the principal provide?

District personnel?

Colleagues?

Are there policies or other factors that get in the way of you teaching STEM subjects in the way you think is best? If so, can you describe them?

Are there supports or structures in place at this school that make successful STEM teaching more likely

than at other schools? If so, can you describe them?

Are there supports that you don't have now that you feel are important to successfully teaching STEM content?

If you were the principal or the district superintendent, what changes might you make to improve STEM teaching and learning?

Follow-up: Why do you think these would be important changes to make?

Is there anything else you could share with me that will help me understand your experience teaching at this school?