ABSTRACT

PREPARING FUTURE ELEMENTARY TEACHERS WITH

A STEM-RICH, CLINICAL, CO-TEACHING

MODELING OF STUDENT

TEACHING

By

Stacey Benuzzi

May 2015

By 2018, science, technology, engineering, and mathematics (STEM) occupations are projected to grow twice as fast as all other occupations combined. The need to educate and produce more STEM graduates is eminent, and research shows that the pipeline to prepare students for STEM fields begins in elementary school. Research also shows that many elementary teachers lack the pedagogical content knowledge (PCK) and confidence to teach STEM subjects. Meanwhile, opportunities for elementary teachers to develop their STEM PCK and confidence in teacher preparation programs or professional development are limited.

To address this problem, programs like, Raising the Bar for STEM Education in California are emerging. A yearlong case study utilizing both qualitative and quantitative methods was employed to examine the program's effectiveness in preparing future elementary teachers to effectively teach STEM subjects through a STEM-rich, clinical, co-teaching model of student teaching. Data collection methods included qualitative interviews, observations through videotaped lessons, documents, and quantitative pre- and post-surveys. The key findings from this study include that the STEM-rich, clinical, co-teaching model of student teaching was successful in increasing pre-service teachers' confidence and expanding their pedagogical knowledge of teaching inquiry-based lessons. Pre-service teachers were willing and excited to teach STEM subjects in their future elementary classrooms at the conclusion of the program. However, the growth in content knowledge and confidence was uneven among the four STEM content areas and there was a lack of integration.

Based on the findings of this study, it is recommended that future STEM professional development programs emphasize the vital importance of STEM fields as the rationale for teaching STEM subjects; build pedagogical content knowledge; integrate STEM subjects through a focus on engineering; explicitly link STEM to Common Core State Standards and Next Generation Science Standards (NGSS); design the STEM professional development around the characteristics of adult learning theory; and foster reflective, collaborative communities of practice. Further recommendations for policy and research are presented and discussed.

PREPARING FUTURE ELEMENTARY TEACHERS WITH

A STEM-RICH, CLINICAL, CO-TEACHING

MODELING OF STUDENT

TEACHING

A DISSERTATION

Presented to the Department of Educational Leadership

California State University, Long Beach

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Education

in Educational Leadership

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May 2015

ACKNOWLEDGEMENTS

This dissertation is dedicated to the late Joan Wilkes. Without Joan's encouragement and enthusiasm, this research study would not have been possible. Her unwavering support of my professional growth as an educator over the years will always remain close to my heart and I greatly appreciate all she did for me.

I would like to thank my committee, Dr. Linda Symcox, Dr. Don Haviland, and Dr. Karen Nakai. I greatly appreciate all of the insight and support you have given to me throughout this entire program and especially during my dissertation. You are all an inspiration to me and I hope I can work with each of you again in the future. I want to especially thank Dr. Linda Symcox, my chair, for all of the time and effort you have given to this project. I greatly appreciate your timely and thoughtful feedback as well as meeting with me so frequently. I am so fortunate to have had such a supportive chair.

Thank you to my family and close friends. You have been my rock throughout this journey and I am so grateful for each of you. Your encouragement and support mean more to me than I can put into words. I love you all and thank you for believing in me. You have motivated me and kept me going during the highs and lows of this journey. I could not have gotten this far without you.

To my fellow cohort six classmates, I am grateful to get to know and learn from each of you throughout this journey. I want to especially thank Keeley Lewis for being my writing partner. Thank you for listening and helping me generate ideas during our long writing days. I could not have completed this study without our writing sessions with our trusty bottle of wine. You are a dear friend, thank you.

Finally, I would like to thank the S. D. Bechtel Jr. Foundation for their support of my research study. I hope that I will be able to contribute toward future work that helps prepare and support elementary teachers to teach STEM subjects effectively. This is such significant work and I am proud to be a part of it.

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PREPARING FUTURE ELEMENTARY TEACHERS WITH A STEM-RICH, CLINICAL, CO-TEACHING MODEL OF STUDENT TEACHING

In the race to space, the Soviet Union shocked the world by being the first to launch its Sputnik satellite, which successfully orbited the Earth in 1957. In response to the humiliation of being surpassed by the Soviets in space exploration, the United States created the National Aeronautics and Space Administration (NASA) and concentrated on supporting science education efforts (Jolly, 2009; Ramirez, 2013). The successful launch of Sputnik forced Americans to analyze their educational system and to better allocate resources in order to develop a science, technology, engineering, and mathematics (STEM) pipeline.

Unfortunately, America finds itself in a similar situation 58 years later. Governmental agencies, academic organizations, news reporters, and universities have all declared that America is in a STEM crisis once again, stating that our children are not prepared for careers in STEM fields (Achieve, 2010; DeJarnette, 2012; Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011; Drew, 2011; Griffiths & Cahill, 2009; Tucker, 2012). Yet, this is a different STEM crisis than nearly 60 years ago in that "rather than competing with one rival, such as the Soviet Union, the United States is operating in a global marketplace" (Jolly, 2009, p. 3).

Today's STEM crisis reveals a critical need for America to educate and produce more STEM graduates. In a report to President Obama, Olson and Riordan (2012) stated that "economic projections point to a need for approximately one million more STEM professionals than the United States will produce at the current rate over the next decade if the country is to retain its historical preeminence in science and technology" (p. i). Craig, Thomas, Hou, and Mathur (2012) reported that in comparison to the average growth projected for all occupations in the United States between 2008 and 2018, STEM employment is projected to increase almost 2 times as fast (Figure 1).

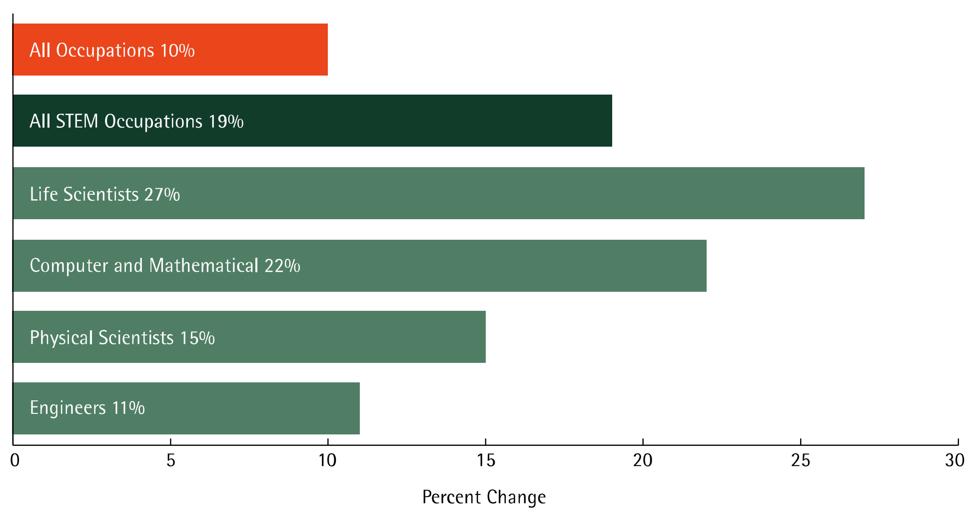

FIGURE 1. Projected growth percentages of occupations in the United States from 2008–2018. Adapted from *Where Will All the STEM Talent Come From?* by E. Craig, R. J. Thomas, C. Hou, and S. Mathur, 2012, p. 3. Copyright 2012 by Accenture.

Craig et al. (2012) found that the percentage of college graduates with a STEM degree varies greatly by country and that the United States rates very low in comparison to many other countries. In 2011, 41% of all of China's college degrees awarded were in STEM majors, while India had 26%, the United Kingdom 22%, Japan 18%, and Brazil

14%; U.S. colleges awarded only 13% of college degrees in STEM. In addition, Bill Gates (2008) shared his concern about the current STEM crisis with the U.S. House of Representatives: "We all want the U.S. to continue to be the world's center for innovation. But our position is at risk: U.S. companies face a severe shortfall of scientists and engineers with expertise to develop the next generation of breakthroughs" (p. 1). In order to rectify the STEM crisis, there is a need to change the American educational system to foster STEM learning in order to meet the demand for STEM graduates now and in years to come.

Problem Statement

The STEM pipeline begins in elementary school, where students learn the foundational skills necessary for success in STEM content (DeJarnette, 2012; Ricks, 2012; Swift & Watkins, 2004). Research suggests that students should begin learning STEM subject matter, such as physics and mathematics, to develop critical thinking skills early in elementary school (DeJarnette, 2012; Ginsburg & Golbeck, 2004; Greenes, Ginsburg, & Balfanz, 2004; Rogers & Portsmore, 2004; Swift & Watkins, 2004). Swift and Watkins (2004) found that "effective science and mathematics instruction must begin in the early grades" (p. 67). Research by DeJarnette (2012) states that early exposure to STEM content in elementary school may increase students' motivation to continue learning STEM in high school and beyond.

Although it is imperative for students to begin learning STEM content as early as possible, research shows that students begin struggling with STEM content early in elementary and middle school. The President's Council of Advisors on Science and Technology (PCAST; 2010) reported to President Obama that less than one-third of eighth graders in the United States were proficient in mathematics and science on the National Assessment of Educational Progress. This report also found that American students are not just lacking proficiency in mathematics and science, but "there is also a lack of interest in STEM fields among many students" (PCAST, 2010, p. vi). This lack of student proficiency and interest contributes to the STEM crisis.

Teacher practice, content knowledge, and confidence influence students' achievement, especially in mathematics (Dembo & Gibson, 1985; Duncan, Diefes-Dux, & Gentry, 2011; Hill, Rowan, & Ball, 2005; Ricks, 2012; Rowan, Chiang, & Miller, 1997; Wayne & Youngs, 2003). However, research also shows that many elementary teachers lack the content knowledge to confidently and effectively teach STEM subjects (Dorph et al., 2011; Drew, 2011; Epstein & Miller, 2011; Otero, 2005; PCAST, 2010), which is one factor that contributes to the STEM crisis in elementary education. The PCAST (2010) report explained that "schools often lack teachers who know how to teach science and mathematics effectively, and who know and love their subject well enough to inspire their students" (p. vi). An analysis of elementary teachers' STEM content knowledge, confidence, and practice is necessary because elementary teachers are "the key, neglected lever on which all other STEM initiatives depend" (Epstein & Miller, 2011, p. 5). As a result of elementary teachers' lack of content knowledge, students may miss the opportunity to build a solid foundation of STEM knowledge in elementary school, a breakdown that then plagues them in middle school, high school, and beyond (PCAST, 2010).

The fact that many elementary teachers lack the confidence and content knowledge to teach STEM effectively is a social justice issue. This is because STEM subjects, specifically mathematics, “act as a ‘gatekeeper’ to economic success, to active citizenship, and to higher education in our society” (D’Ambrosio, 2012, p. 202) and are often seen by society as “an Asian or White male endeavor” (Leonard & Evans, 2012, p. 100). Failure in mathematics and other STEM subjects can close doors to future opportunities and limit access for students. In order to improve STEM education for all students, elementary teachers’ lack of content knowledge and confidence to teach STEM subjects effectively must be examined, because reaching all students is crucial in rectifying the social justice issues in STEM education and in preparing all students for future success.

One way to address the lack of elementary teachers’ STEM content knowledge and confidence is to include more STEM content knowledge and pedagogical strategies in teacher preparation programs by creating STEM-rich teacher preparation programs. The goal of these STEM-rich teacher preparation programs would be to enhance future elementary teachers’ STEM content knowledge and pedagogical strategies before they enter the profession. Hill et al. (2005) affirm “efforts to improve teachers’ mathematical knowledge through content-focused professional development and pre-service programs will improve student achievement” (p. 30). Providing excellent STEM training during future elementary teachers’ pre-service programs, including student teaching, may improve their content knowledge and confidence in teaching STEM subjects.

However, the majority of the existing teacher preparation programs do not specifically address the issue of STEM at the elementary level, and for the teacher preparation programs that do focus on STEM, there is a lack of empirical evidence that addresses the impact of these programs on elementary teachers’ STEM content knowledge and confidence in teaching STEM content. To begin to remedy this problem, California State University, Long Beach (CSULB), implemented a grant-funded STEM-rich teacher preparation program called Raising the Bar for STEM Education: Preparing Elementary Teachers in a Model, Scalable, STEM-Rich Clinical Setting (Raising the Bar for STEM Education in California program) to address elementary teachers' lack of content knowledge and confidence in teaching STEM content (Symcox & Benken, 2012, 2014). This study will investigate the Raising the Bar for STEM Education in California program to learn about its impact on the elementary student teachers' STEM content knowledge and confidence in teaching STEM subjects.

<u>Raising the Bar for STEM Education in California Program</u>

At CSULB, one of its teacher preparation programs, named the Urban Teacher Education Academy in a Clinical Home (UTEACH) requires students to complete a yearlong student teaching program and take their methods courses concurrently in a residency, clinical model program. In the UTEACH program, all of the methods courses are taken at the school site and linked to the student teaching experiences. In the 2013–2014 school year, the UTEACH program was given additional support in STEM through a grant-funded professional development program called Raising the Bar for STEM Education in California: Elementary Teachers in a Model, Scalable, STEM-Rich Clinical Setting (Raising the Bar for STEM Education in California program). This program provided on-going, in-depth professional development focused on STEM content for student teachers and master teachers in order to "create a pipeline of highly qualified elementary STEM instructors and leaders" (Symcox & Benken, 2012, p. 3). University supervisors, methods courses professors, and administrators at school sites were also a part of the Raising the Bar for STEM Education in California program. They all collaborated together and provided support for the student and master teachers as they learned about teaching STEM content to students.

The Raising the Bar for STEM Education in California program was a partnership between CSULB and the local school district. The STEM professional development content was collaboratively developed and facilitated by the university's Colleges of Education and Natural Sciences and Mathematics and the WestEd/K–12 Alliance. Some of the topics addressed in the professional development program included: The Engineering Design Process, Common Core State Standards (CCSS), Next Generation Science Standards (NGSS), note-taking in STEM content areas, the nature of science and science processes, and utilizing technology to support STEM subjects. Additionally, participants learned how to develop and sequence STEM units, create inquiry-based lesson plans for science, plan engineering-based STEM lessons, and implement effective practices for teacher mentoring and collaboration. Each school also held a Family STEM Night to permeate STEM into the culture of the school and its community (Symcox & Benken, 2014).

The Raising the Bar for STEM Education in California program implemented a co-teaching design in which most of the student teachers were given a partner to student teach with throughout their yearlong student teaching assignment. In addition, master teachers attended the STEM-rich professional development along with the student teachers. This co-teaching model fostered collaboration throughout the STEM-rich professional development because the student teachers and master teacher worked together as a team as they learned STEM content knowledge and pedagogical strategies.

The goal of the co-teaching model was to promote teamwork throughout the Raising the Bar for STEM Education in California program (Symcox & Benken, 2014).

Additionally, the student teachers attended a Summer Institute that introduced STEM and focused on connecting engineering to science. The Summer Institute included 4 full days of professional development for the student teachers utilizing Engineering is Elementary (EiE; 2014a) curriculum from the Boston Museum of Science. The mission of EiE is to "support educators and children with curricula and professional development that develop engineering literacy" (EiE, 2014a, para 1). Table 1 shows the daily program of the Summer Institute.

TABLE 1. Summer Institute Daily Program

Day 1	Day 2	Day 3	Day 4
Pre-Survey (STEBI and Open-Ended)	EiE: "A Work in Process: Improving a Play Dough Process" on solids and liquids (EiE, 2014a)	EiE: "A Work in Process: Improving a Play Dough Process" on solids and liquids (EiE, 2014a)	EiE: "Bridge Building" on balance, force, and civil engineering (EiE, 2014a)
What is engineering?		Engineering Design Process	Post-Survey (STEBI and Open-Ended)
Connections to Common Core State Standards and Next Generation Standards			

Note. Adapted from "*Raising the Bar for STEM Education in California: Elementary Teachers in a Model, Scalable, STEM-Rich Clinical Setting* Second Year Report," by L. Symcox and B. Benken, 2014, p. 4. Copyright 2014 by California State University, Long Beach.

Throughout the 2013–2014 school year, student and master teachers attended six STEM-rich professional development sessions. All professional development sessions were held afterschool from 3:30 p.m. to 7:00 p.m. and included dinner for the participants. Table 2 shows the topics of each of the six STEM-rich professional development sessions, while Figure 2 models the yearlong STEM-rich professional development program holistically during the 2013–2014 school year.

TABLE 2. STEM-Rich Professional Development Topics Throughout the 2013–2014 School Year

October 1, 2013	October 29, 2013	November 19, 2013	February 4, 2014	March 4, 2014	May 6, 2014
Exploring the Common Core State Standards for K–5 Mathematics	Exploring the Common Core State Standards for K–5 Mathematics	Exploring the Common Core State Standards for K–5 Mathematics	Learning about technology	Learning about technology	Reflection of the STEM-rich professional development Post-survey

Note. Adapted from "*Raising the Bar for STEM Education in California: Elementary Teachers in a Model, Scalable, STEM-Rich Clinical Setting* Second Year Report," by L. Symcox & B. Benken, 2014, p. 6. Copyright 2014 by California State University, Long Beach.

Additionally, each student teacher and master teacher who participated in the Raising the Bar for STEM Education in California program had the option of completing three additional mathematics or science content courses and one methods course at CSULB to earn their single subject teaching credential in mathematics or science. This additional component of the grant was available to the student teachers or master teachers to do if they chose after completion of the program.

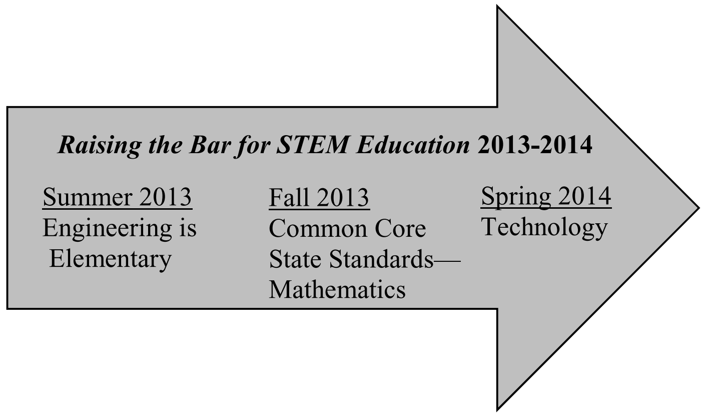

FIGURE 2. STEM-rich teacher preparation program overview.

Implementation of Common Core State Standards (CCSS)

Simultaneously with the Raising the Bar for STEM Education in California program was the implementation of CCSS during the 2013–2014 academic school year. Although CCSS was adopted by California in 2010, 2013–2014 was the first official year of implementation by school districts. CCSS was a nation-wide reform in education, focusing on preparing students to be college and career ready. The standards included English Language Arts and Mathematics, and infused critical thinking and problem solving skills aimed at transferability of knowledge, not memorization of facts and skills (CCSS Initiative, 2015a). CCSS required curriculum and teaching strategies to radically change, in order to align to the new, rigorous standards. This was incredibly challenging for all involved in education during this period of time.

This was an unprecedented change in education and the same group of student and master teachers who participated in the STEM-rich professional development were also responsible for learning about and implementing CCSS at the same time. When the Raising the Bar for STEM Education in California professional development program was created, it was unknown that CCSS would be implemented and generate a high stakes educational reform in California and across the country.

Purpose

In this study, the researcher conducted a yearlong case study involving both qualitative and quantitative methods to learn about student teachers' experiences in the Raising the Bar for STEM Education in California program, which is a STEM-rich, clinical, co-teaching model of student teaching. The purpose of this case study was twofold: it aimed at exploring how the STEM-rich, clinical, co-teaching model of student teaching prepared student teachers to effectively teach STEM content and to study how the implementation of CCSS impacted the STEM-rich, clinical, co-teaching model of student teaching.

Research Questions

This study was guided by the following research questions:

1. How did the STEM-rich, clinical, co-teaching model of student teaching prepare student teachers to effectively teach STEM content?

2. How did the implementation of the educational reform effort for the Common Core State Standards impact the STEM-rich, clinical, co-teaching model of student teaching?

Conceptual Framework

The conceptual framework that guided this dissertation includes pedagogical content knowledge (PCK) and adult learning theory. PCK connected to this study because the STEM-rich student teaching program blended content knowledge with pedagogy in a clinical setting, which aimed at developing student teachers' PCK in

STEM content. Additionally, adult learning theory connected to this research study because its principles focus on learning environments in which adults are the learners. As such, the STEM-rich teacher preparation program was the learning environment and the student teachers, who are adults, were the learners.

Shulman developed the term PCK in his 1986 research and since then many researchers have used the term to explain components that are necessary to teach particular content, such as pedagogical strategies, students' needs, knowledge of assessment, understanding of curriculum, and understanding how to explain a subject so it is comprehensible to others (Appleton, 2003; Avery, 2009; Eilks & Markic, 2011; Shulman, 1986). These habits of mind are critical for teachers to possess to be able to effectively teach a certain subject to their students. Because elementary teachers are responsible for teaching all subjects to their students, they must have strong PCK in all subjects. However, research reveals that elementary teachers lack content knowledge and pedagogical strategies in STEM, thus lacking PCK in STEM content areas (Dorph et al., 2011; Drew, 2011; Epstein & Miller, 2011; Otero, 2005; PCAST, 2010). This must be remedied in order for elementary teachers to be able to effectively teach STEM content to their students to provide the foundation for STEM. This is a daunting challenge, and a challenge that must be addressed in order to improve the teaching and learning of STEM subjects in elementary school.

One way to increase teacher effectiveness is to focus on developing PCK in subjects that elementary teachers struggle with, such as STEM, through ongoing professional development. The STEM-rich, clinical, co-teaching model of student teaching that was investigated in this research study attempted to develop the participants' PCK in STEM subjects through ongoing professional development. This aligns with research in that improving teachers' content knowledge and confidence is not enough. In order to improve teacher practice, teachers must know how to incorporate pedagogical knowledge with their content knowledge in order to impact their practice and become more effective teachers (Appleton, 2003; Avery, 2009; Ball, Thame, & Phelps, 2008; Eilks & Markic, 2011; Hill et al., 2005). Pedagogical knowledge includes teaching strategies, such as inquiry-based learning and classroom discussions to build conceptual understanding. Thus, content knowledge and PCK are intertwined. In relating PCK to STEM, if teachers lack either STEM content knowledge or STEM pedagogical strategies, then they will lack the STEM PCK that enables them to teach STEM effectively to their students (Appleton, 2003). However, someone can have strong content knowledge and weak PCK and struggle to teach the subject. This explains why some people who are brilliant in a particular subject cannot teach it: they lack the necessary PCK to effectively teach. Therefore, it is crucial to improve both elementary teachers' STEM content knowledge and PCK to impact their practice because they go hand-in-hand (Appleton, 2003).

In addition to PCK, adult learning theory was critical to this study because it explains that adults need to be self-directed and internally motivated to learn most effectively (Knowles, 1980; Miroballi, 2010). Adult learning theory assumes the following about the characteristics of adult learners, which emerge as a person matures into adulthood:

1. Self-concept: Self-concept moves from one of being a dependent personality toward one of being a self-directed human being.

2. Experience: There is a growing reservoir of experience that becomes an increasing resource for learning.

3. Readiness to learn: Readiness to learn becomes oriented increasingly to the developmental tasks of social roles.

4. Orientation to learning: Time perspective changes from one of postponed application of knowledge to immediacy of application, and accordingly orientation toward learning shifts from one of subject-centeredness to one of problem-centeredness.

5. Motivation to learn: Motivation to learn is internal. (Miroballi, 2010, para. 2)

In this study, developing and changing the student teachers' self-concept is critical because research reveals that many elementary teachers view themselves as STEM-illiterate. The student teachers' self-concept must be changed in order for them to believe they can effectively teach STEM subjects. Student teachers must feel confident in their own understanding of STEM before they can enhance their PCK in STEM content areas, which is ultimately the goal of the STEM-rich professional development program. Additionally, the professional development created a community of learners in which the student teachers, master teachers, university supervisors, and administrators all collaborated on their learning of STEM.

To summarize adult learning theory's five characteristics, adult learners are different than children and need to be treated differently when learning. Gomez (2012) explains that adult learners "must have purpose in what they are learning. Learners must understand how this learning experience will help them solve a problem or complete a future task" (p. 42). Thus, adult learning theory explains that adults should be involved in their learning and that their experience provides the best vehicle for learning (Gomez, 2012; Knowles, 1980). In this study, the STEM-rich, clinical, co-teaching model of student teaching focuses on student teachers, who are adult learners, as they develop their PCK in STEM content through a yearlong, STEM-rich professional development program.

PCK and adult learning theory framed this study to learn about effective elements of the STEM-rich, clinical, co-teaching model of student teaching for adult elementary school student teachers. Adult learning theory explains that adults' motivation to learn is internal. As a result, it is expected that student teachers will learn best if their learning of STEM content is connected to practice, enhances their self-concept, and is self-motivated (Knowles, 1980; Miroballi, 2010). In order for the STEM-rich, clinical, co-teaching model of student teaching to be as effective as possible, it should incorporate the principles of adult learning theory while emphasizing PCK in STEM subjects, because these theories are known to impact teachers' learning. Figure 3 models the conceptual framework utilized in this study.

This model in Figure 3 demonstrates how the core of the conceptual framework is PCK and that adult learning theory encompasses PCK and the entire STEM-rich, clinical, co-teaching model of student teaching.

Significance

The goal of this study is to provide educational leaders with information on creating and implementing effective STEM-rich professional development programs for elementary teachers across the state of California in both K–12 school districts and in higher education elementary teacher preparation programs. The findings from this study

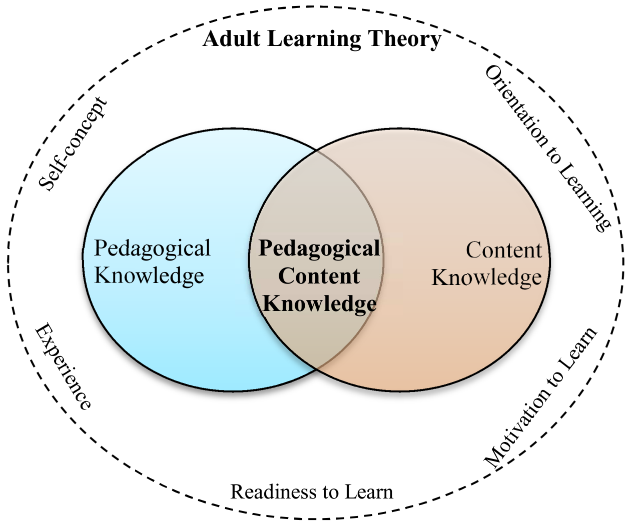

FIGURE 3. Conceptual framework intertwining PCK and adult learning theory.

may help remedy the deficiencies of STEM teaching and learning in elementary school by researching the impact of a STEM-rich, clinical, co-teaching model of student teaching for elementary teachers in California. The literature reveals that elementary education is foundational for learning STEM critical thinking skills; however, elementary teachers are typically under-prepared to teach STEM content effectively (Dorph et al., 2011; Epstein & Miller, 2011; PCAST, 2010). This study is critical because research on STEM-rich elementary teacher preparation programs is limited. As such, this study is unique in that it is a yearlong case study focused on researching a STEM-rich, clinical, co-teaching model of student teaching. This study will contribute to the gap in knowledge on STEM in elementary education by providing information on STEM professional development and STEM elementary teacher preparation programs, not programs focused on only science or mathematics.

The findings of this study identify specific components of the STEM-rich, clinical, co-teaching model of student teaching that effectively prepared future elementary teachers in teaching STEM content. The findings of this study, in addition to other key literature and the conceptual framework of PCK and adult learning theory were utilized in identifying essential elements of effective STEM professional development. The objective of describing essential elements of effective STEM professional development, based on the findings of this study in conjunction with other research, is to assist in the development of a widespread, effective elementary STEM-rich professional development and/or STEM-rich elementary teacher preparation program at other California State University campuses. Because STEM is an area that is seriously lacking in current elementary professional development and elementary teacher preparation programs, dissemination of the results of this study may benefit educational leaders throughout the P–16 system who are involved in elementary teaching and/or the training and development of elementary teachers.

Additionally, this study seeks to learn about how the implementation of CCSS impacted the STEM-rich, clinical, co-teaching model of student teaching. Because this case study occurred during the 1st year of CCSS implementation in California, the findings will shed light on how CCSS impacts other reform efforts in education, and how STEM and CCSS align.

Operational Definitions

To assist the reader's comprehension of the terms used in this research study, the following key terms are defined as follows:

STEM: Science, technology, engineering, and/or mathematics.

Elementary school teacher: A teacher who teaches transitional Kindergarten to sixth grade.

Pre-service teacher: A student teacher who is a in a teacher preparation program through a college or university. The pre-service teacher works directly with an in-service teacher and a university supervisor. This is another term for student teacher.

In-service teacher: A teacher who is employed by a school district and who is currently teaching. In this study, the in-service teacher is also the master teacher working with the pre-service teacher as a mentor.

University supervisor: This is a professor at the university/college that teaches the student teaching course. The university supervisor works directly with both the pre-service and in-service teachers, and serves as a liaison between the two. The university supervisor observes the student teachers in classrooms, meets with them regularly, and evaluates them throughout the student teaching experience.

Teacher preparation program: In order to earn a teaching credential in California, one must complete a teacher preparation program at a college or university. The teacher preparation programs generally include methods courses to teach pedagogy and conclude with student teaching.

UTEACH: An elementary teacher preparation program at CSULB called the "Urban Teacher Education Academy in a Clinical Home (UTEACH)." It is an unusual program in that pre-service teachers complete a yearlong student teaching program and take their methods courses concurrently. This program is a residency, clinical model program in that all of the courses are taken at the school site and linked to their student teaching experiences. Student teachers are placed in pairs in their student teaching assignment to develop a co-teaching model. In the 2013–2014 school year, the UTEACH program was overlaid with an on-going STEM-rich professional development program for both the student teachers and master teachers to learn STEM content and pedagogical strategies to effectively teach STEM content.

Pedagogical content knowledge (PCK): Components of content knowledge and teaching that are necessary to teach a particular subject effectively, including pedagogical strategies, understanding students' needs, knowledge of assessment, understanding of curriculum, and understanding how to explain a subject so it is comprehensible to others (Appleton, 2003; Avery, 2009; Eilks & Markic, 2011; Shulman, 1986).

Adult learning theory: Adult learners are different than children and need to be treated differently when learning. Adult learning theory explains that adults should be involved in their learning and that their experience provides the best vehicle for learning (Gomez, 2012; Knowles, 1980). The five characteristics of adult learning theory are self-concept, experience, readiness to learn, orientation to learning, and motivation to learn (Miroballi, 2010).

Effective teaching: Teaching that leads to student success. Key factors leading to effective teaching include "knowledge of teaching and learning, subject matter knowledge, and experience" (National Council for Accreditation of Teacher Education [NCATE], 2014, p. 3).

Confidence: A belief in oneself that you can do something well; self-assurance. Confidence is a concept embedded in the theoretical construct self-efficacy and connects to self-concept in adult learning theory.

Assumptions of the Study

The assumptions of this study include:

1. STEM education will continue to be a focus in all levels of education, even with the adoption of the new Common Core State Standards.

2. Future elementary teachers may benefit from a teacher preparation program that focuses on STEM content and pedagogy.

Limitations and Delimitations of the Study

The limitations and delimitations of this study include:

1. The findings are not generalizable; however, transferability would depend on the credibility and authenticity of the data.

2. The interview and survey data were self-reported by participants.

3. Only one site from the STEM-rich student teaching program was included in this research study because of access to a gatekeeper at the school.

4. This study does not seek to understand student learning or student achievement in STEM content.

Conclusion

The purpose of this dissertation is to assess the ways in which the STEM-rich, co-teaching model of student teaching prepares future elementary teachers to effectively teach STEM subject matter. A conceptual framework intertwining PCK and adult learning theory will be used throughout the study to provide a lens in which characteristics of adult learners and PCK are blended to learn about the STEM-rich student teaching program for future elementary teachers.

Because of the current STEM crisis in America, research on STEM at all levels, including elementary education, needs to be conducted to learn ways of rectifying the crisis. Thus, this study has a great significance and potential to impact policy, practice, and research.

Chapter 2 will review the relevant literature on elementary teachers' content knowledge and confidence in teaching STEM content. Additionally, the literature review will focus on current models of elementary teacher preparation programs, specifically those that include co-teaching or clinical models. Literature on STEM-rich teacher preparation programs will also be included.

Chapter 3 will describe the research methodology, including the design, methods, and procedures of this case study research project. It will describe the participants, site, data analysis projections, and trustworthiness of the researcher.

Chapter 4 will present the findings of the study. The researcher will triangulate the various data methods in describing the findings using themes that answer the research questions about the STEM-rich, clinical, co-teaching model of student teaching.

Finally, Chapter 5 will provide a discussion of the findings, as well as its implications for future policy, practice, and research. This chapter will summarize and conclude the study.

CHAPTER 2

LITERATURE REVIEW

The purpose of this study was to explore how a STEM-rich, clinical, co-teaching model of student teaching prepared future elementary teachers to effectively teach STEM content. Student teachers in the Raising the Bar for STEM Education in California program received STEM-rich professional development in addition to a clinical, co-teaching model of student teaching. A second goal of this study was to examine how the implementation of CCSS impacted the Raising the Bar for STEM Education in California program.

This literature review includes the following three topics to provide background information and to frame this research study: (a) elementary teachers' STEM content knowledge, confidence, and practice; (b) elementary teacher preparation programs; and (c) professional development programs. Areas of limited research and gaps in the literature are acknowledged in order to identify how this study will fit within the current body of literature and how it will contribute to the knowledge base.

Elementary Teachers' STEM Content Knowledge, Confidence, and Practice

One factor that contributes to the STEM crisis is that many elementary teachers lack the content knowledge and confidence needed to effectively teach STEM subjects (Appleton, 2003; Dorph et al., 2011; Epstein & Miller, 2011; Griffiths & Cahill, 2009; Otero, 2005; PCAST, 2010; Wallace & Louden, 1992). In a report to President Obama, PCAST (2010) explained:

> Great STEM teachers have at least two attributes: deep content knowledge in STEM, and strong pedagogical skills for teaching their students STEM. . . . Too few of these teachers are in the Nation's classrooms, in part because of a lack of professional respect, the inconsistency of teacher preparation programs, and the salary disparity relative to other STEM fields. (p. 77)

There is a need for elementary teachers to have strong content knowledge and pedagogical knowledge in teaching STEM subjects in order to prepare students to enter the STEM pipeline. However, research reveals a disconnect with what is required of elementary teachers and what is the reality of the majority of elementary teachers' content knowledge, confidence, and practice in teaching STEM subjects. The next sections will describe the literature on elementary teachers' STEM content knowledge, confidence, and practice.

<u>Elementary Teachers' STEM Content Knowledge</u>

One explanation as to why elementary teachers lack content knowledge in STEM subjects is that many elementary teachers are generalists (Epstein & Miller, 2011; Weiss, Banilower, McMahon & Smith, 2001). In other words, many elementary teachers major in education or liberal studies which do not focus solely on learning STEM content, but rather on learning generalizations about a variety of subjects. In the United States, Weiss et al. (2001) surveyed 5,728 science and mathematics teachers across the country with a 79% response rate to find that approximately 80% of K–4 teachers majored in elementary education. In California, only 8% of all of the elementary multiple subject teaching credentials issued from 2010 to 2011 majored in STEM fields, while 24% majored in education and 20% majored in the social sciences (Commission on Teacher Credentialing, 2012). At CSULB, the data are even more alarming. From 2008 to 2013, 75% of CSULB elementary multiple subject credential students majored in liberal studies or education, while less than 1% of students majored in STEM fields (Teacher Preparation Advising Center, 2013).

Research by Eilks and Markic (2011), who studied teacher preparation programs, states, “there is a broad consensus that teachers need expertise in the subject matter area they teach” (p. 151). However, many elementary teacher preparation programs do not adequately prepare future elementary teachers with the content knowledge to effectively and confidently teach STEM. Epstein and Miller’s (2011) research found, “course requirements in teacher preparation programs are generally weak, both in terms of math content and pedagogy” (p. 7). Additionally, elementary teacher preparation programs require pre-service teachers to take methods courses for science and mathematics, but not for technology or engineering, which are the other aspects of STEM.

A study by Corcoran (2009) for her doctoral dissertation utilized mixed methods to survey 21 in-service elementary teachers and conduct in-depth interviews with six teachers from those originally surveyed to learn about their science content knowledge. The findings of this study suggest that elementary teachers believe they have a deeper understanding of science content knowledge than they really do. Their perceptions do not align with reality of their content knowledge. The researcher believes, “with some degree of confidence, that these participants seem to have inflated views of their own science knowledge” (Corcoran, 2009, p. 120). This study concludes that even though elementary teachers may believe they have a deep understanding of science content, the evidence points to the contrary. This study supports the claim that many elementary teachers lack science content knowledge and understanding, which can be inferred to a lack of STEM content knowledge.

Therefore, the majority of the literature concludes that elementary teachers lack the content knowledge necessary to effectively teach STEM subjects to their students due to their lack of preparation in their undergraduate course of study and their teacher preparation program. This lack of content knowledge impacts elementary teachers' confidence in teaching STEM subjects. The next section will analyze the research on elementary teachers' confidence in teaching STEM subjects.

Elementary Teachers' Confidence in Teaching STEM

Many elementary teachers have low confidence in teaching mathematics and science content because of their lack of content knowledge and preparation in these subjects (Appleton, 2003; Dembo & Gibson, 1985; Epstein & Miller, 2011; Sterling, 2006; Weiss et al., 2001). Mathematics and science are only two components of STEM; however, there is a gap in the literature on elementary teachers' confidence in teaching STEM subjects as a whole, so this section of the literature review only includes studies on mathematics and science.

Epstein and Miller (2011) explain why a teacher's low self-confidence in teaching mathematics is problematic:

> A child who has difficulty with math is taught to believe that he or she is just not a "math person." In contrast, it is not an option as to whether or not one is a "reading person." All teachers know how to read, but not all have confidence with basic math. Indeed, many elementary school teachers are math-phobic, putting them at a major disadvantage in teaching math and imparting confidence in their students. (p. 6)

This math-phobia described by Epstein and Miller can be projected to a STEM-phobia for elementary teachers, because if elementary teachers lack confidence with mathematics, it can be inferred that these teachers will lack confidence in teaching STEM subjects since mathematics is one component of STEM and, arguably, the most commonly taught component. This STEM-phobia is problematic for elementary teachers because it negatively impacts their confidence in teaching STEM subjects, which impacts their ability to teach STEM content effectively to their students.

Furthermore, research has discovered that a teacher's attitudes and self-efficacy in teaching STEM subjects, specifically science, can affect how much time is actually spent teaching science: positive feelings lead to more time spent on science teaching, while negative feelings lead to less time spent on science teaching (Sterling, 2006). Sterling (2006) conducted a qualitative multiple-case, multiple-site case study on six beginning elementary teachers to learn about what impacts their science teaching for her doctoral dissertation. A limitation of the study is that the results are not generalizable. However, in support of Sterling's (2006) findings, Bandura (1986) generalized that people evade tasks they believed surpass their abilities.

In continuing with research on confidence in teaching science, a national survey by Weiss et al. (2001) concluded that many elementary teachers do not feel comfortable or prepared to teach science. The researchers found:

> In science, elementary teachers are less likely than middle and high school teachers to feel prepared to develop students' conceptual understanding of science. . . . Roughly 75 percent of the elementary teachers feel very well qualified to teach reading/language arts, approximately 60 percent feel very well qualified to teach mathematics, and about 25 percent feel very well qualified to teach science. (p. 30)

With three-fourths of surveyed elementary teachers reporting that they do not feel qualified to teach science, the findings illustrate elementary teachers' lack confidence in teaching science, which is a major component of STEM. It can be inferred that if the majority of elementary teachers are not confident in teaching science, then they are also not confident in teaching other STEM subjects such as technology and engineering. Research from Lewis, Harshbarger, and Dema (2014) support the findings that elementary teachers lack confidence in teaching science.

Ultimately, research shows that teachers' STEM content knowledge and confidence are interrelated. Wimsatt (2012) found a statistically significant relationship between elementary teachers' science content knowledge and their self-efficacy in teaching science. A limitation of the quantitative research conducted by Wimsatt is that a convenience sampling procedure was used rather than a random sampling and the researcher only had a 12% response rate in her survey. Therefore, the results are not generalizable even though a quantitative methodology was utilized. Nonetheless, in support of Wimsatt's study, Appleton (2003) found that some elementary teachers avoided teaching science because they were not comfortable with the content.

Dweck's (2006) research on mindset also impacts teachers' confidence in their ability to teach certain subjects. Teachers with a growth mindset believe that effort is the determining factor in being able to effectively teach a subject to their students, not intelligence. However, teachers with a fixed mindset believe that their intelligence impacts their ability to effectively teach their students. This is important because none of the studies on teachers' confidence in teaching mathematics and science addressed participants' mindset. Ultimately, teachers who have a growth mindset are more confident than those with a fixed mindset. When studying teachers' confidence, mindset must be addressed. Research on teachers with a growth mindset's confidence in teaching STEM subjects is necessary to fully understand elementary teachers' confidence in teaching STEM subjects.

Elementary Teachers' Pedagogy and Practice in Teaching STEM

The use of pedagogical strategies that support the teaching of STEM subjects, such as inquiry-based lesson design and classroom discussions, is another area of research on the teaching and learning of STEM. Research conducted by Ricks (2012) on elementary students found that "classroom instructional practices play a critical role in the development of student motivational beliefs and behaviors" (p. 26).

It is widely reported in the literature that some subjects in elementary education, especially science, are not taught frequently because reading and mathematics are the focus in elementary education due to high-stakes testing and No Child Left Behind requirements (Dorph et al., 2011; Epstein & Miller, 2011; Sterling, 2006; Weiss et al., 2001). In California, science is not tested until fifth grade. Epstein and Miller (2011) found:

> In recent years, schools have devoted more time to math and reading because these subjects are included in the standardized tests on which state accountability systems are based. Science, in contrast, is often given far less attention in the elementary grades. (p. 8)

Additionally, research by Darling-Hammond et al. (2008) surveyed 1,000 public school elementary teachers to learn that 85% of the participants reported that subjects that are not tested are given less time and attention in the curriculum compared to subjects that are tested on the summative state test. Thus, teachers often neglect content that is not tested in that they do not spend a lot of time teaching untested subjects in elementary education. This has implications for STEM subjects because STEM is not currently tested on the end-of-year state tests. Mathematics is a subject on its own that is tested on state tests. However, STEM as a whole is excluded from these high stakes tests, and this may contribute to reasons why teachers do not spend a lot of time teaching STEM subjects in elementary school.

Moreover, national survey research of 5,728 science and mathematics teachers by Weiss et al. (2001) found that a considerable less amount of time was spent teaching science than other subjects in elementary education. "In 2000, grade K–3 self-contained classes spent an average of 115 minutes [daily] on reading instruction and 52 minutes on mathematics instruction, compared to only 23 minutes on science instruction" (Weiss et al., 2001, p. 48). The practice of spending a limited amount of time teaching science continued into upper elementary classes, but was not as profound as lower elementary grades. This may be explained by the testing of science in fifth grade. Similar to Weiss et al.'s (2001) findings, Dorph et al. (2011) found that 40% of surveyed elementary teachers revealed that they teach science 60 minutes or less per week.

Elementary teachers teach mostly basic concepts in science rather than complex and higher-level concepts (Weiss et al., 2001). Lecture and class discussions were the instructional strategies predominately used in elementary education to teach science. To engage and interest students, science should be taught using hands-on activities and experiments. Lewis et al. (2014) found that teaching only basic concepts in science was more prevalent with at-risk students. In order to teach higher-level science concepts, elementary teachers should use inquiry-based instructional strategies instead of direct instruction (Lewis et al., 2014).

To support and add on to the described research, Steele and Hillen (2012) concluded that teacher preparation programs must focus on STEM by making connections across the disciplines and by using a variety of representations. This would help elementary teachers be able to teach STEM content using integration across the curriculum and using a variety of teaching strategies rather than only lecturing. Research by Lewis et al. (2014) supported the use of an interdisciplinary model of teaching through the use of inquiry-based instructional strategies to teach STEM content. Unfortunately in practice, "STEM tends to function in isolation from other core subjects" (Hoachlander & Yanofsky, 2011, p. 2).

In analyzing the literature on STEM in elementary education, adult learning theory provides a unique perspective. Rather than focusing on student achievement in STEM, adult learning theory focuses on the adults in the equation: the teachers. The literature states that a key-contributing factor to the STEM crisis is that many elementary teachers do not have a solid understanding of STEM content and are not confident in teaching STEM. One way to improve elementary teachers' content knowledge and confidence in teaching STEM is to incorporate STEM content into elementary teacher preparation programs. In the next session of the literature review, an overview of teacher preparation programs will be explored.

Teacher Preparation Programs

The goal of elementary teacher preparation programs is to prepare future elementary teachers to be effective teachers in Grades K–6. Elementary teachers in

California usually complete a 5th-year teacher preparation program at a college or university in order to earn their multiple subject teaching credential. However, there are other types of teacher preparation programs available, such as undergraduate or internship programs in which the programs can be completed in 4 years earning a bachelor's degree and multiple subject teaching credential (Darling-Hammond, 2006). Teacher preparation programs generally include methods classes that focus on teaching strategies and pedagogy and conclude with student teaching. Student teaching is the field experience in which pre-service teachers put theory into practice with elementary students in an actual classroom (Manzey, 2010).

A major challenge of teacher preparation programs for elementary teachers is that the students enter the program with varying levels of content knowledge. Because most teacher preparation programs are a 5th year of study, they begin where the students' previous learning of the content areas leave off. Unfortunately, many teacher preparation programs assume mastery of content knowledge and solely focus on pedagogical knowledge in the methods courses (Darling-Hammond, 2006).

To alleviate this problem, it is recommended that teacher preparation programs emphasize both content knowledge and pedagogical knowledge. Content knowledge should be embedded into the pedagogical strategies most appropriate for teaching conceptual understanding and critical thinking skills for that subject (Ball & Cohen, 1999; Darling-Hammond, 2006). Therefore, building PCK in all subjects taught in elementary education should be the focus of teacher preparation programs (Ball & Cohen, 1999; Darling-Hammond, 2006; Shulman, 1986).

Although there are many types of teacher preparation programs with a variety of student teaching programs available in California, elements of effective teacher preparation programs will be discussed in the next section.

Elements of Effective Teacher Preparation Programs

Because there are so many different types of teacher preparation programs in California, it is essential to research them to learn about what makes a teacher preparation program effective. "The goals for teacher education today are not just to prepare teachers to deliver a curriculum or get through a book but actually to ensure learning for students with a broad assortment of needs" (Darling-Hammond, 2006, p. 8). Preparing future teachers is a daunting challenge for teacher preparation programs because teachers "must be diagnosticians, knowledge organizers, and skilled coaches to help students master complex information and skills" (Darling-Hammond, 2006, p. 10).

An in-depth case study conducted by Darling-Hammond (2006) included interviews, surveys, and observations of graduates from many different teacher preparation programs across the United States as well as studying syllabi and course assignments to identify exemplary teacher preparation programs. Once exemplary programs were identified, common characteristics were identified to learn about elements of effective teacher preparation programs. The common features include:

1. A common, clear vision of good teaching permeates all coursework and clinical expectations;
2. Well-defined standards of practice and performance are used to guide and evaluate coursework and clinical work;

3. Curriculum is grounded in knowledge of child and adolescent development, learning, social contexts, and subject matter pedagogy, taught in the context of practice;

4. Extended clinical experiences are carefully developed to support the ideas and practices presented in simultaneous, closely interwoven coursework;

5. Explicit strategies help students (1) confront their own deep-seated beliefs and assumptions about learning and students and (2) learn about the experiences of people different from themselves;

6. Strong relationships, common knowledge, and shared beliefs link school- and university-based faculty; and

7. Case study methods, teacher research, performance assessments, and portfolio evaluation apply learning to real problems of practice. (Darling-Hammond, 2006, p. 41)

Teacher preparation programs should strive to encompass the features of powerful teacher education described by Darling-Hammond (2006) in order to prepare future elementary teachers to be able to teach all students to think critically, reason, and problem solve.

In the next section of this literature review, different types of student teaching programs for pre-service elementary teachers will be analyzed. The types of student teaching programs range from traditional models to co-teaching and peer coaching models to clinical models to science-focused models of student teaching.

Types of Student Teaching Programs Available

Student teaching is the key component for connecting theory to practice in teacher preparation programs (Borko & Mayfield, 1995; Valencia, Martin, Place, & Grossman, 2009). There are a variety of student teaching programs available in teacher preparation in California. During student teaching, pre-service teachers work with a university supervisor. The role of the university supervisor is to support their learning and act as a liaison between the university and the school site. The university supervisor plays a pivotal role in pre-service teachers' student teaching experiences, regardless of the type of student teaching program they are in. Research by Darling-Hammond, Hammerness, Grossman, Rust, and Shulman (2005) describes an ideal student teaching experience for pre-service teachers:

> Typically, the ideal placement in which student teachers are supported by purposeful coaching from an expert cooperating teachers in the same teaching field who offers modeling, co-planning, frequent feedback, repeated opportunities to practice, and reflection upon practice while the student teacher gradually takes on more responsibility. (p. 409)

However, this experience described by Darling-Hammond et al. (2005) varies greatly across teacher preparation programs, regardless of the type of student teaching program offered.

Elementary student teaching programs include traditional, co-teaching, peer coaching, clinical, yearlong, and science-focused models. Literature on the pros and cons of each type of model of student teaching for pre-service elementary teachers will be described.

Traditional student teaching programs. Traditional student teaching is when "a teacher education student is placed in a classroom with a single cooperating teacher for varying lengths of time, a term or perhaps a semester" (Bullough et al., 2003, p. 57). In traditional student teaching programs, student teachers work with one master teacher in primary grades and one master teacher in intermediate grades for a certain amount of time with each master teacher. Thus, student teachers work with a total of two different master teachers in two grade levels in an elementary school during their student teaching program. Student teachers assume the responsibility of the classroom and practice teaching fairly quickly. However, the quality of learning by the student teacher varies greatly and little is known about what is actually learned in the student teaching experience (Borko & Mayfield, 1995; Bullough et al., 2003; Valencia et al., 2009). In a traditional student teaching model, the amount and frequency of guidance and support from the master teacher to the student teacher varies greatly in terms of lesson planning, teaching strategies, and reflecting (Borko & Mayfield, 1995).

A critical challenge of traditional student teaching programs is to enhance both the content knowledge and pedagogical knowledge of pre-service teachers (Ford & Strawhecker, 2011). This is due to the structural organization of the traditional student teaching programs and traditional teacher preparation programs. Prior to entering a traditional teacher preparation program, students take content courses as part of their undergraduate course of study. Professors in the college of that particular discipline typically teach the content courses. Once students are in the teacher preparation program they take methods courses to learn pedagogy on how to teach each discipline. Professors in the College of Education typically teach the methods courses during a traditional teacher preparation program (Ford & Strawhecker, 2011). For example, a mathematics content course is usually taught by the College of Mathematics and Natural Sciences before entering a teacher preparation program. A mathematics methods course, on the other hand, is taught by the College of Education during the multiple subject teacher preparation program. Once all of the methods courses are completed, pre-service teachers enter a semester long student teaching program. During their traditional student teaching experience, pre-service teachers attempt to apply the theory they learned regarding pedagogical strategies in their methods courses with the content learned in their undergraduate program. For many pre-service teachers, their PCK is not evenly practiced and applied during their traditional student teaching experiences (Ford & Strawhecker, 2011).

In the next section, the literature on co-teaching student will be described, which is an alternative type of student teaching program.

Co-teaching model of student teaching. An alternative model of student teaching is co-teaching. In co-teaching model of student teaching, student teachers are placed in pairs in their student teaching assignment. Thus, student teachers have a partner as well as a mentor teacher to rely on and learn from during the experience. Researchers have several names for this model of student teaching: apprenticeship, paired placements, triad model, and co-teaching. Tobin and Roth (2005) explain, "co-teaching is premised on the idea that by working with one or more colleagues in all phases of teaching (planning, conducting lessons, debriefing, grading), teachers *learn* from others" (p. 314).

A qualitative study by Bullough et al. (2003) researched co-teaching student teaching at Brigham Young University by comparing the experience of single student teachers with co-teaching student teachers in elementary schools. The researchers analyzed lesson plans and time logs and interviewed the student teachers to create multiple-case studies for single placed student teachers (traditional student teaching) and partner placed student teachers. The researchers found that the co-teaching model of student teaching encouraged collaboration, while single placed student teachers felt isolated. Student teachers in the co-teaching model took pedagogical risks, had strong classroom management, and increased student learning (Bullough et al., 2003). Additionally, "partner-placed mentors and student teachers became interdependent members of instructional teams. Among partners and mentors conversation about teaching was frequent, consistent, and open" (Bullough et al., 2003, p. 68). This study also concluded that the mentor teachers thought that the co-teaching model was more beneficial than traditional student teaching. However, the researchers found that the student teachers were worried that the co-teaching model did not reflect the reality of the teaching after completion of their student teaching program (Bullough et al., 2003).

Building on the research of Bullough et al. (2003), an additional qualitative research study on a co-teaching model of student teaching was conducted at Brigham Young University by Nokes, Bullough, Egan, Birrell, and Merrell Hansen (2008). The researchers interviewed 26 student teachers at the conclusion of their 15-week co-teaching model of student teaching to learn about their perceptions of the program. The findings of this study were very similar to Bullough et al.'s research in that the strengths of the co-teaching model were that the student teachers were willing to try a variety of instructional strategies and take risks. A reported weakness of the co-teaching model was that student teachers did not receive "the real experience of solo teaching" (Nokes et al., 2008, p. 2173). An additional finding of the study is that partner student teachers dialogued and reflected on their teaching due to their shared experiences in the co-teaching model of student teaching. These key findings support the characteristics of adult learning described in adult learning theory.

The qualitative study by Goodnough, Osmond, Dibbon, Glassman, and Stevens (2009) also researched the co-teaching model of student teaching to learn about its effectiveness and limitations. Goodnough et al. used semi-structured interviews, electronic journals, school visits, and planning meetings to collect data to learn about the co-teaching model of student teaching (triad model). The themes that emerged regarding the benefits of this model were learning from each other, support, feedback, and confidence. "The most significant benefit of the triad model, as identified by both the pre-service and the cooperating teachers, was the collaboration that materialized between the pre-service teacher dyads" (Goodnough et al., 2009, p. 290). The limitations of the triad model are pre-service teacher autonomy and interdependence. More research needs to be conducted to determine if these limitations are universal or specific to this study.

Research by Crawford (2007) found that a co-teaching model of student teaching shows promise in supporting student teachers in learning how to teach science through inquiry because of the support student teachers are given in compared to traditional models of student teaching. Co-teaching promotes the development of PCK to teach science through inquiry. Manzey's (2010) case study research corroborates Crawford's findings in that the pre-service teachers attempted to use components of inquiry in their science lessons when their master teacher modeled it.

> In co-teaching, candidates have opportunities to not only see their mentors model appropriate inquiry strategies, candidates also have the opportunities to immediately practice these strategies with their mentor's help. . . . Maximizing the educational value of candidates' classroom experience may well be related to collaboration with their mentor. (Manzey, 2010, p. 6)

A co-teaching model of student teaching emphasizes collaboration among the student teachers and master teacher (Manzey, 2010).

Overall, research reveals that a co-teaching model of student teaching is promising because it engages the student teachers and the master teacher in high levels of collaboration and support throughout the student teaching experience (Crawford, 2007; Goodnough et al., 2009; Manzey, 2010; Tobin & Roth, 2005). Student teachers who participate in co-teaching feel less isolated and more confident about their student teaching program (Bullough et al., 2003).

However, it has also been found that the success of co-teaching varies based on the master teacher. A critical component of co-teaching is the mentoring and coaching by the master teacher. Research shows that it is essential to provide the master teacher professional development in mentoring student teachers using a co-teaching structure (Manzey, 2010; Tobin & Roth, 2005). Additional research on the professional development of the master teachers in a co-teaching model of student teaching needs to be conducted to learn more about their impact on success of student teachers in a co-teaching model.

A common concern regarding the co-teaching model of student teaching is that pre-service teachers may not be prepared for the reality of teaching; in-service teachers tend to be by themselves in their classroom, not in partners like in the co-teaching model (Bullough et al., 2003; Nokes et al., 2008). The counterargument to this concern is that the majority of the literature found that the student teachers benefited from co-teaching due to increased collaboration and support (Crawford, 2007; Goodnough et al., 2009; Manzey, 2010; Tobin & Roth, 2005).

In the next section, the literature on another type of student teaching program, peer coaching, will be described. There are many similarities between co-teaching and peer coaching models of student teaching. Often, co-teaching and peer coaching are used in conjunction with one another during student teaching programs. However, for purposes of this literature review, peer coaching has been separated from co-teaching to learn more about its impact on pre-service teachers.

Peer coaching model of student teaching. A peer coaching model of student teaching is a variation of co-teaching and, at times, peer coaching and co-teaching are implemented concurrently in student teaching programs. Peer coaching is defined by Goker (2006) as:

> The process of two teachers working together in and out of the classroom to plan instruction, develop support materials, and watch one another work with students. Peer coaching is non-evaluative, based on classroom observation followed by feedback, and intended to improve specific instructional techniques. (p. 240)

In comparison to the traditional model of student teaching that promotes autonomy, a peer coaching model of student teaching emphasizes collaboration among the student teachers to improve instruction (Britton & Anderson, 2010; McAllister & Neubert, 1995). Researchers have several names for peer coaching: peer mentoring, peer supervision, reflective peer coaching, and cognitive coaching.

"Peer coaching is a formative process that facilitates introspection and self-awareness prior to, during, and after teaching" (Vidmar, 2005, p. 138). Key components of peer coaching include establishing trust, collaboration, conferencing; observations with data collection; and analysis and reflection (Britton & Anderson, 2010). These components establish the peer coaching cycle of pre-conferencing, observing, and post-conferencing. In pre-conferencing, the student teachers meet before the lesson to decide who will teach and who will observe, to go over the objectives and activities in the lesson, and identify what specific aspect of the lesson he/she wants feedback on. The partner who is observing will record specific data that connects to the portion of the lesson the other student teacher wants feedback on during the observation cycle of peer coaching. Finally, during the post-conference the student teachers collaboratively go over the lesson based on the recorded feedback and reflect on the successes and challenges of the lesson (Vidmar, 2005).

Peer coaching is a highly successful method with pre-service teachers because it promotes collaboration and reflection (Britton & Anderson, 2010; Goker, 2006; McAllister & Neubert, 1995). All of the participants in Britton and Anderson's (2010) qualitative research study "communicated a desire to use peer coaching again, and each person stated that the process could be useful in the future" (p. 312). Thus, peer coaching is an advantageous model of student teaching and can be added to a different model of student teaching, such as co-teaching.

Lu (2010) conducted a literature review on eight studies about peer coaching that spanned the years 1997 to 2007 to look for similarities and differences in peer coaching in the studies. All of the studies focused on student teachers and found that the student teachers collaborated and supported each other through the peer coaching process. Additionally, all but one of the studies provided training on the peer coaching process to the student teachers in its study, although the duration of the training varied from study to study. Common findings of the studies in Lu's literature review were that peer coaching improved instructional strategies, improved professionalism, and offered student teachers emotional support. Some of the studies reported that peer coaching made the student teachers "feel more relaxed, comfortable, and confident" (Lu, 2010, p. 751). Therefore, literature on peer coaching reveals that it is an effective model of student teaching because it impacts pre-service teachers' confidence and skills in teaching.

Peer coaching aligns with the characteristics of adult learning theory and PCK in that pre-service teachers are expanding their knowledge of content and pedagogy while connecting their learning to their experiences and developing their self-concept as teachers. Additionally, peer coaching builds upon pre-service teachers' motivation and orientation of learning because each pre-service teacher chooses what to focus on during cycles of peer coaching. Thus, peer coaching emphasizes choice, reflective practice, and collaboration, which are all important for adult learners.

In the next section of this literature review, clinical student teaching programs will be described.

Clinical student teaching programs. Clinical student teaching programs connect theory to practice. In most clinical student teaching programs, pre-service teachers complete coursework concurrently with student teaching (Darling-Hammond, 2006). Because pre-service teachers complete their methods courses while student teaching, they are able to apply their learning about pedagogical theory to practice. A common complaint of teacher education is that it focuses too much on theory, not on the skills needed in practice (Darling-Hammond, 2006). Clinical models of student teaching alleviate this issue of focusing too much on theory in teacher preparation programs by simultaneously teaching pre-service teachers pedagogical theory in methods courses and then having them apply the theory learned during student teaching. Clinical models of student teaching benefit pre-service teachers in that "extended clinical experiences, interwoven with coursework, helped [pre-service teachers] learn how to conceptualize teaching and enact their ideas in practice" (Darling-Hammond, 2006, p. 44). This is different than traditional models of student teaching because in clinical models of student teaching there is "supervised clinical work—tightly integrated with coursework—that allows candidates to learn from expert practice in schools that serve diverse students" (Darling-Hammond, 2014, p. 550).

In a case study of exemplary teacher preparation programs across the United States, Darling-Hammond (2006) found a common characteristic of successful programs include cohesive clinical student teaching programs. These exemplary programs require pre-service teachers to complete journals reflections or other guided observations to focus the student teachers on certain aspects of teaching. Darling-Hammond (2006) explains:

> The clinical experiences are also tightly tied to simultaneous coursework and seminars that pose tasks and problems to be explored in the clinical setting and that support analysis and further learning about practice. This combination of theoretical and practical study is a particularly important change from the traditional approach, which front-loads theory, does not enable applications, and therefore does not support grounded analysis of teaching and learning. (p. 154)

Graduates of teacher preparation programs that include a clinical model of student teaching report feeling more prepared than their peers (Darling-Hammond et al., 2005). Additionally, clinical student teaching programs require a partnership between the school and university, so there must be open communication in order to create a program that prepares the pre-service teacher for the teaching profession (Darling-Hammond, 2014).

Next, research will be examined on yearlong student teaching programs.

Yearlong student teaching programs. Building upon the research on clinical models of student teaching, research by Darling-Hammond et al. (2005) explain that when student teaching programs include "extended clinical experiences (at least thirty weeks) that reflect the program's vision of good teaching, are interwoven with coursework, and are carefully monitored" (p. 406) that graduates report significantly higher feelings of preparedness. When student teaching programs were yearlong compared to semester-long, research reveals positive effects of student teachers (Darling-Hammond et al., 2005).

Furthermore, a more recent study by Darling-Hammond (2014) further describes that student teaching that lasts a full academic year allows pre-service teachers to "grow roots on their practice, which is especially important if they are going to learn to teach in learner-centered ways that require diagnosis, adaptations to learners' needs, intensive assessment and planning, and a complex repertoire of practice" (p. 551).

In the next section, science-focused programs will be portrayed.

Science-focused student teaching programs. Although there is a gap in the research on STEM-specific student teaching programs, there is literature on science-focused student teaching programs, specifically inquiry-based student teaching (Horvath, 2008; Manzey, 2010; Stein, 2006). This section of the literature review will examine studies focused on science student teaching programs for elementary teachers even though STEM science student teaching programs for elementary teachers would be more appropriate for this study. The lack of research on STEM-specific student teaching programs for elementary teachers is noteworthy and is an area of need for future research.

Horvath (2008) conducted a qualitative research study on 13 pre-service teachers in an inquiry-based student teaching program. Of the 13 pre-service teachers, seven shifted their perspective of inquiry-based science teaching to incorporate more hands-on experiences, including collecting and analyzing data, and critical thinking activities when teaching science.

As previously explained in the co-teaching section of this literature review, Manzey's (2010) study of a co-teaching model of student teaching showed promise of effectively utilizing inquiry in teaching science by the student teachers. The co-teaching model is credited with being the vehicle that promoted inquiry-based teaching in science; however, this model of student teaching successfully implemented a science-focused program.

Stein's (2006) doctoral dissertation focused on exploring which science experiences helped successful elementary science teachers teach science effectively. It was found that these successful science teachers had the opportunity to teach science in their student teaching experience. The implications of this research are that all elementary pre-service teachers need the opportunity to teach science in their student teaching program.

The lack of mathematics-rich student teaching programs and STEM-specific student teaching programs in the literature is unfortunate because Ford and Strawhecker (2011) claim, "the best undergraduate elementary education preparation is a product of a partnership between mathematics and pedagogy, linked to meaningful field experience" (p. 2). This research highlights the need for STEM-specific research on elementary student teaching programs to learn about their impact on pre-service teachers' PCK. This gap in the research is how my research study will add to the literature and why it is significant because the Raising the Bar for STEM Education in California program is a STEM-rich, clinical, co-teaching model of student teaching.

Because the Raising the Bar for STEM Education in California program included ongoing STEM-rich professional development in addition to the clinical, co-teaching model of student teaching, the next section of the literature review will include research on professional development programs. The literature will focus on the types of professional development programs available, elements of effective professional development, and limitations of professional development.

Professional Development Programs

Teachers who participate in professional development feel more prepared for various classroom activities (Farris, Lewis, Parsad, & Greene, 2000). The goal of professional development is to improve the quality of teaching and learning; however, there is not one full-proof method of professional development that works for all teachers. The many different modalities of professional development, such as, traditional, horizontal, and online, and each have their own pros and cons (Garet, Porter, Desimou, Birman, & Yoon, 2001; Gomez, 2012; McNamara, 2010). In order to be effective, professional development needs to be purposeful, targeted, and ongoing (Darling-Hammond & McLaughlin, 1995; Eilks & Markic, 2011) regardless of the type of professional development. The effectiveness of professional development is limited by the lack of follow-up, limited time, and non-alignment with principles of adult learning theory (Avery, 2009; Farris et al., 2000; McNamara, 2010). Research on professional development focused specifically on STEM will also be presented.

Types of Professional Development Programs Available

Several different types of professional development are available for teachers: traditional, horizontal learning, and online. The literature mostly focuses on professional development in mathematics and science, not the integration of STEM content; thus, the studies used in this section include mathematics and science professional development or generalized studies that do not specify a content focus.

Traditional professional development. One common method of professional development is called "traditional professional development" in the literature (Avery, 2009; Eilks & Markic, 2011; Garet et al., 2001). Traditional professional development workshops are the most familiar and most criticized type of professional development (Garet et al., 2001). Avery (2009) explains the characteristics of traditional professional development:

> Traditionally, professional development has been conducted through in-service school workshops. From a traditional model of staff development, the school or district commissions an outside curriculum expert or consultant to conduct a one day training session on generic approaches to delivering subject content matter. (p. 12)

Gomez (2012) also found that traditional professional development tended to last for a single day or for short sequenced workshops. Additionally, the results of a survey by Farris et al. (2000) of 5,253 elementary, middle, and high school teachers across the United States from the National Center for Educational Statistics found "teacher participation in professional development was likely to be short term, typically lasting for one to eight hours" (p. 10). These brief professional development sessions have been found to be ineffective on their impact on teachers' PCK, confidence, and practice (Avery, 2009; Eilks & Markic, 2011; Farris et al., 2000; Garet et al., 2001; Gomez, 2012). One reason that traditional professional development tends to be ineffective is its lack of including principles of adult learning theory into its design. For example, motivation and readiness to learn are elements of adult learning theory, but traditional professional development tends to ignore teachers' motivation and rarely connects the new learning specifically to participants' prior experiences. In order to improve traditional methods of professional development, principles of adult learning theory, including self-concept, readiness to learn, motivation to learn, orientation of learning, and experiences, should be the foundation for designing professional development to meet the needs of the participating teachers.

Horizontal learning professional development. Another type of professional development is horizontal learning. This involves learning from peers, such as learning in school networks, peer coaching, lesson study, and mentoring (Garet et al., 2001). A key difference between traditional professional development and horizontal learning is that horizontal learning tends to occur during the school day or during regular planning time. Garet et al. (2001) surveyed 1,027 mathematics and science teachers with a 72% response rate to discover that in learning from peers from the same school, "professional development may help sustain changes in practice over time. . . . Professional development may contribute to a shared professional culture" (p. 922). One shortcoming of this study is that the research subjects were limited to participants in the Eisenhower program, so although the number of people who responded to their survey was high, the results cannot be confidently generalized to the entire nation because of the restricted sample.

Birman, Desimone, Porter, and Garet (2000) use the term "collective participation" for horizontal learning and found that school networks support teacher learning by connecting the activities into an integrated program that is consistent and built upon previous activities. Lesson study professional development emphasizes collaboration and focuses on "improving teachers' content knowledge and instructional skills as teachers plan a research lesson, teach and observe students' thinking and learning behaviors, and then revise and re-teach the lesson" (Harle, 2008, p. vi). Lesson study builds teachers' PCK as they work together and learn from one another.

Additionally, horizontal learning professional development incorporates elements of adult learning theory. Because horizontal learning emphasizes learning from peers at their school site, the learning is connected to teachers' experiences and fosters a motivation for learning focused on collaboration. Horizontal learning can improve teachers' self-concept because the support is ongoing and targeted (Harle, 2008).

<u>Online professional development</u>. The third type of professional development is online learning. Online learning may help teachers improve their content knowledge and practice (McNamara, 2010). McNamara's (2010) study "showed that participants highly valued online professional development because of the convenience and the ability to self-pace and differentiate their learning" (p. 149). This mixed methods study of online professional development surveyed 328 K–12 teachers from 15 states and interviewed three people as part of a case study to learn that 57% of the participants found the self-paced design of the professional development was beneficial to their learning. Participants indicated that the online professional development was motivating because they could differentiate the learning pace to meet their own needs. This aligns with the

characteristics of adult learning theory. One of the strengths of the study is its methodology, because McNamara (2010) used a mixed methods approach to both quantitatively survey and qualitatively conduct multiple case studies to triangulate her findings. A limitation of the research is that the data were self-reported gains in learning through the surveys and interviews.

In comparison with traditional models of professional development, online learning provides teachers with more choice and flexibility. Adult learning theory explains that adult learners learn best when the learning is built upon their motivation and when they are ready to learn. Online learning professional development encompasses adult learning theory because teachers are able to learn at their own pace and the learning is differentiated to meet their needs. In traditional professional development, teachers are not given as much flexibility and the learning is not self-paced or differentiated.

In summary, there are various models of professional development for teachers as learners. Traditional, horizontal learning, and online learning are common types of professional development programs. When professional development incorporates elements of adult learning theory and PCK, it tends to be more successful in building teachers' content knowledge and improving instructional strategies. The next section of this literature review will concentrate on effective elements of professional development that impact teachers' content knowledge and practice.

Elements of Effective Professional Development Programs

Research shows that in-depth professional development that lasts over time can lead to authentic change in teachers' PCK, confidence, and practice (Darling-Hammond & McLaughlin, 1995; Eilks & Markic, 2011; Garet et al., 2001; Van Driel, Beijaard,

&Verloop, 2001). Both quantitative and qualitative studies have been conducted to learn about effective professional development; however, there is limited research specifically on STEM professional development programs. This is because professional development is generally conceptualized around separate disciplines, such as mathematics and science or around classroom strategies, not the integration of STEM content areas. In this section, I will focus on elements of effective professional development programs, regardless of content area, which can be inferred to align with components of effective STEM professional development.

Darling-Hammond and McLaughlin (1995) found that effective professional development must intertwine the experiences of teachers to include them both as learners and teachers to produce effective professional development. Characteristics of high-quality professional development must:

> 1. Engage teachers in concrete tasks of teaching, assessment, observation, and reflection that illuminate the processes of learning and development;
>
> 2. Be grounded in inquiry, reflection, and experimentation that are participant-driven;
>
> 3. Be collaborative, involving a sharing of knowledge among educators and a focus on teachers' communities of practice rather than on individual teachers;
>
> 4. Be connected to and derived from teachers' work with their students;
>
> 5. Be sustained, ongoing, intensive, and supported by modeling, coaching, and the collective solving of specific problems of practice; and
>
> 6. Be connected to other aspects of school change. (Darling-Hammond & McLaughlin, 1995, p. 598)

Darling-Hammond and McLaughlin (1995) state teachers learn by "doing, reading, and reflecting; by collaborating with other teachers; by looking closely at students and their work; and by sharing what they see. This kind of learning enables teachers to make the leap from theory to accomplished practice" (p. 598). This research directly connects to adult learning theory because it states that professional development must build on the experience of the teacher learners in order to be effective.

A research study by Garet et al. (2001) supported Darling-Hammond and McLaughlin's (1995) findings. Their results indicate:

> Sustained and intensive professional development is more likely to have an impact, as reported by teachers, than is shorter professional development. Our results also indicate that professional development that focuses on academic subject matter (content), gives teachers opportunities for "hands-on" work (active learning), and is integrated into the daily life of the school (coherence), is more likely to produce enhanced knowledge and skills. (Garet et al., 2001, p. 935)

This research study emphasizes the importance of professional development focusing on content knowledge, incorporating opportunities for active learning, and providing coherence between the professional development topic and other learning activities (Garet et al., 2001).

Additionally, a literature review by Van Driel et al. (2001) found that "long-term staff development programs are needed to actually change experienced teachers' practical knowledge" (p. 12). Thus, traditional professional development programs are not as effective in changing teaching practices because teachers need to alter their knowledge and beliefs in order to transform their practice over time. Although Van Driel et al. researched and synthesized literature on professional development in science education, a critique and limitation of this article is that it is not based on empirical research.

Moreover, Eilks and Markic (2011) conducted an action research study over a 6-year time period to learn about a professional development program that focuses on teachers' PCK in science. This study focused on collaboration with university faculty to strengthen science instruction. The study illustrated the importance for effective professional development to last longer than a 1-day workshop. The study determined that the professional development was more effective when more time was devoted to it because teachers began to buy in and change their practice with continued support of the professional development. "When teachers are involved in long-term innovative research . . . their attitudes and competencies change with respect to testing and implementing new ideas in a positive sense. . . . Their PCK changes permanently" (Eilks & Markic, 2011, p. 9). Professional development that focuses on both content knowledge and pedagogical knowledge is critical in developing teachers' PCK, which is contributes to a change in practice. Professional development that focuses on only content knowledge or only pedagogical knowledge is not sufficient in impacting teachers' PCK or their practice (Eilks & Markic, 2011; Van Driel et al., 2001).

All of the research studies on effective elements of professional development connect to adult learning theory, because adult learners learn best when the learning is based on their experiences and they are involved in the process of learning. The research supports PCK and adult learning theory's principles in that adult learners are more successful in expanding their PCK when they buy-in to what they are learning and connect it to their experiences.

The next section of this literature review will focus on limitations of professional development programs.

Limitations of Professional Development Programs

Professional development that lacks follow-up and is not ongoing tends to be ineffective in changing teacher practice (Farris et al., 2000). Additionally, the impact of professional development is limited when it does not connect to teachers' experiences or prior knowledge, nor allow teachers to feel connected to one another (Avery, 2009; McNamara, 2010).

One main limitation of traditional professional development is the lack of follow-up and the limited time for the professional development sessions (Avery, 2009; Farris et al., 2000; McNamara, 2010). "Formal professional development, typically consisting of school and district staff development programs has been criticized for being short term and lacking in continuity and adequate follow up" (Farris et al., 2000, p. 4).

Additionally, "teachers, who are often left out of the professional development planning loop, feel that the professional development lacks working theories of how adults learn and does not recognize the dynamics and complexity that coincide with teaching" (Avery, 2009, p. 12). This limitation of professional development programs connects to adult learning theory because the theory explains that adult learners should be involved in their learning through active engagement and making connections to their prior experiences. Thus, when teacher learners are left out of professional development plans but are required to attend, they may not be motivated according to adult learning theory's principles and Avery's (2009) findings.

In non-traditional professional development such as online professional development, limitations occur when teachers do not feel connected to others. McNamara (2010) explained, "when the opportunity does not exist to participate in an online community of practice, teachers are frustrated and tend to not like the experience" (p. 131). Thus, it is important for online professional development to include opportunities for teachers to create an online community using email, chat, or a threaded discussion board.

In the next section, research on STEM professional development will be described.

STEM Professional Development

Although there is a need for STEM professional development for teachers of all grade levels, but especially elementary teachers, there is a limited amount of research on STEM professional development. This study on the Raising the Bar for STEM Education in California program will contribute to this area of literature regarding STEM professional development for elementary teachers.

A study by Strimel (2013) on professional development focused on integration of STEM subjects through a focus on engineering and found promising results. A quantitative survey was administered to 63 elementary, middle, and high school STEM teachers who chose to participate in the professional development with an 84% response rate. The findings revealed that teachers felt better prepared to be an effective STEM teacher after the professional development. Additionally, the researcher concluded that even though most of the teachers were secondary, "technology and engineering can be an asset for engaging primary students in STEM education and careers at a young age" (Strimel, 2013, p. 454).

Another study investigated the impact of a 3-day summer institute professional development program on elementary teachers' attitudes, efficacy, and confidence in teaching STEM (Nadelson, Callahan, Pyke, Hay, Dance, & Pfiester, 2013). The study utilized quantitative analysis to answer its research questions with 32 participants. The Science Teaching Efficacy Belief Instrument (STEBI) was utilized in this quantitative study. The STEM professional development found positive results in that the participating teachers' attitudes toward engineering increased as did participants' confidence in teaching STEM. Although the study found promising results on a STEM professional development program, the findings cannot be generalizable or replicable because the program was not described so that the reader could understand what was included in STEM professional development program.

Furthermore, research by Nadelson, Seifert, Moll, and Coats (2012) examined a grant-funded professional development program for teachers in Grades 4 through 9 to learn how it increased participants' "comfort, efficacy, and perceptions of their effectiveness to teach STEM" (p. 72). Again, STEBI was utilized in this quantitative study. The findings of this study found that efficacy for teaching STEM subjects was related to comfort with teaching STEM and the use of inquiry. Additionally, the study concluded:

> The outcome of our analysis suggests that our professional development intervention influenced how the participants defined, planned for, and perceived how they implement STEM education. The substantial increase in the level of sophistication of the responses indicates the intervention was effective for increasing perceptions of engagement and knowledge of STEM. Perhaps the most promising result was the substantial increase in motivation for teaching STEM, which may be attributed to the participants' increased content/subject matter knowledge and perceptions of their ability to teach STEM. (Nadelson, et al., 2012, p. 80)

The findings postulate that the STEM professional development was impactful in preparing fourth through ninth grade teachers to teach STEM effectively to their students using inquiry. There are many similarities to this professional development program and the Raising the Bar for STEM Education in California program, so it will be interesting to see if any of these findings are duplicated in my study.

To conclude the literature on professional development, research suggests that although the type of professional development may vary from traditional to horizontal learning to online, professional development that is effective is aligned with adult learning theory in that it is specific, ongoing, and connects to teachers' experiences. In contrast, professional development that is ineffective tends to lack follow-up and does not connect to teachers' experiences and motivations. Although there is some research on STEM professional development, there is a need for further research to learn about effect professional development programs and how they impact teachers' PCK and confidence in teaching STEM subjects.

Conclusion

The literature on STEM in elementary education states that many elementary teachers lack STEM content knowledge and PCK. One explanation for this lack of content knowledge is that elementary teacher preparation programs tend to not focus on STEM content knowledge and PCK (Epstein & Miller, 2011; Weiss et al., 2001). Research shows that content knowledge and PCK are intertwined and in order to improve teachers' practice, both content knowledge and PCK must be increased (Appleton, 2003). Literature on elementary teachers' lack of confidence in teaching STEM explains that low confidence may be affected by the lack of STEM content knowledge. Researchers have referred to elementary teachers' limited confidence in teaching STEM as a "STEM-phobia" (Epstein & Miller, 2011). This STEM-phobia may be a factor as to why some elementary teachers avoid teaching science and why a considerable less amount of time is spent on teaching science in elementary school compared with other subjects (Sterling, 2006).

One way to improve elementary teachers' content knowledge, confidence, and practice may be to change teacher preparation programs. The literature explains that co-teaching and peer coaching models of student teaching positively impact pre-service teachers in that they feel supported and collaborate with others throughout their program (Crawford, 2007; Goodnough et al., 2009; Lu, 2010; Manzey, 2010; Tobin & Roth, 2005). Research on student teaching programs that incorporate both co-teaching and peer coaching need to be studied in order to learn about their impact on STEM PCK and confidence in teaching STEM for pre-service elementary teachers.

Literature on professional development emphasizes the need for on-going, targeted, collaborative professional development. Professional development that emphasizes the principals of adult learning theory and builds teachers' PCK tend to be effective models of professional development. While professional development programs that do not utilize elements of adult learning theory and do not focus on both content knowledge and pedagogical knowledge tend to be ineffective professional development programs.

The Raising the Bar for STEM Education in California program combines an elementary teacher preparation program with a yearlong STEM-rich professional development program to prepare future elementary teachers to effectively teach STEM subjects. The Raising the Bar for STEM Education in California program connects to the literature, because it incorporates a distinctive design of on-going STEM-rich professional development that coincides with a yearlong, clinical, co-teaching, peer coaching model of student teaching. This unique program will be researched to learn about its strengths and weaknesses in preparing future elementary teachers to effectively teach STEM subjects. Because there is a gap in the literature on STEM-focused elementary teacher preparation programs and limited research on STEM-focused professional development programs for elementary teachers, this research study will add to the knowledge base on how to prepare elementary teachers for teaching STEM subjects to their students.

The next chapter will describe this study's research design, participants, site, methods, data collection procedures, and data analysis processes.

CHAPTER 3

METHODOLOGY

The purpose of this study was to explore how the STEM-rich, clinical, co-teaching model of student teaching prepared elementary student teachers to effectively teach STEM content. Another goal of this research study was to investigate the impact of the implementation of CCSS on the STEM-rich, clinical, co-teaching model of student teaching. A conceptual framework blending PCK and adult learning theory was used throughout the study to explore the STEM-rich, clinical, co-teaching model of student teaching for future elementary teachers. This study was guided by the following research questions:

1. How did the STEM-rich, clinical, co-teaching model of student teaching prepare student teachers to effectively teach STEM content?

2. How did the implementation of the educational reform effort for the Common Core State Standards impact the STEM-rich, clinical, co-teaching model of student teaching?

To address the research questions, a case study design was utilized to gather qualitative in-depth, systematic, and comprehensive information using various data sources, such as interviews, observations, and documents (Patton, 1999), as well as quantitative pre- and post-survey data. "A case study research design is a set of qualitative [and quantitative] procedures to explore a bounded system in depth" (Clark & Creswell, 2010, p. 242).

General Methodological Design and Defense of Chosen Design

A case study design utilizing both qualitative and quantitative methods was used to answer the research questions in this study, since a case study provides the researcher with a "holistic understanding of a problem, issue, or phenomenon within its social context. . . . A case study aims to build understanding by addressing research questions and triangulating 'thick descriptions' with interpretations of those descriptions in an ongoing iterative process" (Hesse-Biber & Leavy, 2011, p. 256). A case study design enabled the researcher to make pragmatic methodological choices that focus on the case, while preserving a holistic perspective within the social context of the case (Hesse-Biber & Leavy, 2011; Yin, 2014). A case study design enabled the researcher to focus on the whole picture while utilizing multiple data collection methods.

This study was a single-case study design because it studied one bounded unit, collected multiple forms of data, and analyzed data for in-depth understanding. The elementary school site where the student teachers taught bound this single-case study. Yin (2014) supports the use of a single-case study as a methodological design when investigating a contemporary phenomenon within the real-world context.

Participants

The participants in this study were 10 student teachers, five master teachers, and one university supervisor who participated in the Raising the Bar for STEM Education in California program*,* which consisted of a STEM-rich, clinical, co-teaching model of student teaching at Seaside Elementary School, in a large urban school district in

Southern California. Participants for this study were chosen using purposeful sampling from a total of 35 master teachers, three university supervisors, and 38 UTEACH student teachers who participated in the yearlong STEM-rich, clinical, co-teaching student teaching program through CSULB and a local school district during the 2013–2014 school year. Clark and Creswell (2010) explain that purposeful sampling is when the researcher "intentionally selects sites and individuals to learn about or understand the central phenomenon" (p. 242).

All of the student teachers were in the UTEACH teacher preparation program at CSULB, which is a residency, clinical, co-teaching program that requires students to complete a yearlong student teaching program and take their methods courses concurrently at the school site where they are student teaching. In the 2013–2014 school year, the UTEACH program included additional support in STEM content and pedagogy through a grant-funded program called Raising the Bar for STEM Education in California: Elementary Teachers in a Model, Scalable, STEM-Rich Clinical Setting (Raising the Bar for STEM Education in California program). This program provided a yearlong, in-depth professional development focused on STEM and was a partnership between CSULB and a local school district.

All of the master teachers had a minimum of 13 years of teaching experience and had been master teachers previously. In their previous experiences as master teachers, they were a part of the UTEACH program through CSULB without the additional STEM professional development. Two of the master teachers taught fifth grade, two taught second grade, and one taught transitional Kindergarten. The university supervisor had been a university supervisor for 14 years, 10 of those years in the UTEACH program. All of the participants volunteered to be a part of the study.

Site

A total of four elementary schools in a local school district participated in the Raising the Bar for STEM Education in California program. Of the four schools, Seaside Elementary School was chosen as the site for this research study because of access to a gatekeeper. The university supervisor at Seaside Elementary School was a professional colleague of the researcher and was willing to assist with recruitment of the master and student teachers assigned to Seaside Elementary School. All of the UTEACH student teachers at Seaside Elementary School participated in this study. The school site was what bounded the case study.

Seaside Elementary School had approximately 600 students in transitional Kindergarten through fifth grade during the 2013–2014 school year. Ten point nine percent of the students at Seaside Elementary School were English Language Learners (ELLs), and of those students who were ELLs, most spoke Spanish with a few speaking Khmer and Vietnamese. Thirty nine point eight percent of students were socioeconomically disadvantaged and 28.8% of students were students with disabilities. The breakdown of students’ race/ethnicity at Seaside Elementary School was 5.5% Asian, 1.0% Pacific Islander, 3.2% Filipino, 41.3% Hispanic or Latino, 7.0% African American, 37.1% White, 3.0% two or more races, and 1.9% not reported (Ed Source Data, 2014).

Data Collection Methods

As Yin (2014) explains, "a case study's unique strength is its ability to deal with a full variety of evidence—documents, artifacts, interviews, and observations" (p. 12). In a case study, multiple methods are used to collect in-depth and extensive data about the case (Hesse-Biber & Leavy, 2011). In this case study, both qualitative and quantitative data sources were collected in order to triangulate the data, including qualitative interviews, observations through videotaped lessons, documents, and quantitative pre- and post-surveys. Table 3 shows the connection of research questions to the data sources used to answer each research question.

TABLE 3. Data Sources Used to Answer Research Questions

Research questions	Data sources
1. How did the STEM-rich, clinical, co-teaching model of student teaching prepare future elementary teachers to effectively teach STEM content?	Interviews Videotaped observations Lesson plans with reflections Journal reflections Peer coaching forms Pre- and post-surveys
2. How did the implementation of the educational reform effort for the Common Core State Standards impact the STEM-rich, clinical, co-teaching model of student teaching?	Interviews Lesson plans with reflections Journal reflections Peer coaching forms

Interviews

Semi-structured, open-ended interviews were conducted individually with each student teacher in May 2014 to learn about their perception of the STEM-rich, clinical, co-teaching model of student teaching. Some questions asked in the student teacher interviews focused on their content knowledge and confidence in teaching STEM, as well as their feeling of preparedness to enter the teaching profession after a year of STEM-rich professional development (Appendix A). Each interview lasted approximately 45 minutes and was conducted at Seaside Elementary School in a private conference room in the school's office. The interviews were digitally recorded and transcribed for data collection purposes.

Semi-structured open-ended interviews were conducted in grade level specific focus groups with the master teachers in May 2014 to learn about their perceptions of their student teachers' STEM content knowledge and confidence in teaching STEM subjects after completing the yearlong STEM-rich, clinical, co-teaching model of student teaching (Appendix B). Because all of the master teachers had previously been master teachers before the STEM-rich professional development was added to the student teaching program, the master teachers were asked to compare and contrast their perceptions of the UTEACH student teaching program with and without the STEM-rich professional development. Each focus group lasted approximately 45 minutes and was conducted at Seaside Elementary School in a private conference room in the school's office. The interviews were digitally recorded and transcribed for data collection purposes.

The interview protocols for the student and master teachers were created based on the literature; each interview question in the interview protocols was mapped to one or more research question(s) and to relevant literature (Appendix C). Then, experts in the field checked the protocols and gave feedback on specific wording of certain protocol questions. The interview protocols were piloted before the study. After piloting the interview protocols, the protocols were adjusted by breaking apart compound questions and included probes that encouraged the interviewee to go more in-depth in the explanations and answers of certain questions.

The interviews with the student teachers and the focus group sessions with the master teachers addressed the research questions. Each student teacher was asked to describe how the STEM-rich, clinical, co-teaching model of student teaching impacted their confidence in teaching STEM content, as well as their overall preparedness to enter the teaching profession. The student teachers were also asked to describe how the STEM professional development impacted their content knowledge and pedagogical strategies for teaching STEM content. All of the interview protocol questions for the student teachers were designed to gather data about how the STEM-rich, clinical, co-teaching model of student teaching prepared them to effectively teach STEM content. The focus group sessions with the master teachers helped triangulated the information gathered from the student teachers.

Observations Through Videotaped Lessons

Each student teacher videotaped two lessons, one in fall and the other in spring, as part of the requirements of their student teaching program. The fall videotaped lesson could be on any subject, but the spring videotaped lesson was either a science or mathematics lesson. Thus, the fall lesson was only included as data if it was on a STEM subject; other subjects were excluded. The student teachers then watched their lesson individually and completed a reflection form, reflecting on their instruction and classroom management (Appendix D). For the spring STEM lesson, student teachers had the option of including student work with their lesson and reflection. The student teachers connected their lesson to what they had learned in the STEM professional development and explained this connection in their reflection. The connections ranged from instructional practices to specific activities to integration of STEM content into other subjects. These reflections directly related to the study's research questions and were used to triangulate the findings from other data sources, including the interviews. Triangulating the multiple data sources strengthens the construct validity of the single-case study (Yin, 2014).

When viewing the videotaped lessons, the researcher took field notes on the instructional strategies that were utilized by the student teachers during the lesson, as well as the content taught in the lesson. This aligns with the conceptual framework because the researcher focused on the PCK demonstrated by student teacher during the lesson. In addition to the use of field notes, the videotaped lessons were transcribed and included in the data analysis process.

Documents

Multiple documents were collected from the student teachers throughout the 2013–2014 school year, such as lesson plans, reflections on lessons, journal reflections, peer coaching forms, and additional documents about the Raising the Bar for STEM Education in California program.

Lesson plans with reflections. Science and mathematics lessons were collected throughout the 2013–2014 school year to reflect student teachers' growth throughout their student teaching program. The lesson plans included an open-ended reflection from the student teachers to capture their thoughts and perceptions throughout the program, including their confidence in teaching STEM content. The reflections included challenges and successes in teaching the STEM lessons and revisions they would make to the lesson after teaching it to improve the lesson. Some of the lesson plans included student work and some reflections connected the lesson plan to what was learned in the STEM-rich professional development.

Additionally, the student teachers were required to create one lesson plan for their fall science methods course that was collected as data for this case study. This lesson plan was written in the 5E format and included revisions. The 5E lesson plan is a specific format for writing inquiry-based science lesson plans that includes five stages: engagement, exploration, explanation, elaboration, and evaluation (Appendix E). Lesson plans that corresponded with the videotaped lessons were also collected.

The lesson plans were used to answer the research questions by identifying specific components of the STEM-rich professional development that impacted the student teachers' STEM teaching, specifically the creation of science lessons utilizing the 5E inquiry-based science lesson plan.

<u>Peer coaching forms</u>. Because the student teachers had a partner student teacher in this co-teaching model of student teaching, they completed peer coaching forms throughout their yearlong student teaching program. The peer coaching forms asked students to give feedback to one another through a formal protocol (Appendix F). In peer coaching, the student teachers met to decide who would teach a lesson and who would give feedback. The person teaching asked their partner to focus on specific aspects of their lesson, such as input/guided practice, using cooperative learning methods, using higher level questioning strategies, being well-prepared and organized, using Specially Designed Academic Instruction in English (SDAIE) strategies, assessing students

throughout the lesson, and pacing/timing. The person observing the lesson gave specific feedback on the focus areas previously identified by citing strengths of the lesson and giving examples for change and recommendations. The peer coaching process helped student teachers be reflective and learn from one another. Two to three peer coaching forms were collected for each pair of student teachers as data for this study. These documents provided insight to the student teachers' strengths and challenges throughout their yearlong student teaching program and helped answer the research question on how the STEM-rich, clinical, co-teaching model of student teaching prepared future elementary teachers to effectively teach STEM subjects.

Journal reflections. Throughout the yearlong student teaching program, student teachers were required to keep a journal in which they reflected on their experiences and progress while student teaching. In their journals, student teachers reflected on strengths and challenges of their teaching, as well as their confidence in teaching STEM content. Many student teachers connected their learning from the STEM-rich professional development sessions to what they did in the classroom with students. Two to three journal reflections per student teacher were collected and analyzed as data for this case study.

Additional documents about the STEM-rich professional development program. Documents supporting the Raising the Bar for STEM Education in California program were collected, such as pictures of the professional development sessions, the grant proposal to the S. D. Bechtel Jr. Foundation, and the 1st and 2nd year report to S. D. Bechtel Jr. Foundation.

Pre/Post Surveys

Pre-surveys were given to each student teacher during the first STEM professional development session in September 2013. The purpose of the surveys was to measure student teachers' self-efficacy beliefs in teaching science and mathematics. The same surveys were administered again at the end of the program in May 2014 as a post-survey to measure the changes in student teachers' self-efficacy beliefs in teaching science and mathematics after completing the yearlong STEM-rich professional development program.

Instruments. The STEBI was developed by Riggs and Enochs (1990) to measure elementary teachers' efficacy beliefs in science teaching (Appendix G). The STEBI includes two categories: personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). For the purpose of this study, only the PSTE portion of the STEBI was analyzed because it focuses on teachers' self-efficacy in teaching science. The STEBI has strong reliability and validity. The reliability of the PSTE questions has an alpha coefficient of 0.92 (Riggs & Enochs, 1990). All questions use a 5-point Likert Scale, with 1 representing "strongly disagree," 2 representing "disagree," 3 representing "uncertain," 4 representing "agree," and 5 representing "strongly agree." Example questions about efficacy beliefs from the STEBI are "I am continually finding better ways to teach science"; "Even when I try very hard, I don't teach science as well as I do most subjects"; and "I find it difficult to explain to students why science experiments work" (Riggs & Enochs, 1990).

The Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) was developed by modifying the STEBI in order to measure elementary teachers' efficacy beliefs in teaching mathematics (Appendix H). The MTEBI includes two categories: personal mathematics teaching efficacy (PMTE) and mathematics teaching outcome expectancy (MTOE). Again, only the PMTE portion of the survey was utilized in this study. The MTEBI has strong reliability and validity. The reliability of the PMTE questions has an alpha coefficient of 0.88 (Enochs, Smith, & Huinker, 2000). All questions use a 5-point Likert Scale, with 1 representing "strongly disagree," 2 representing "disagree," 3 representing "uncertain," 4 representing "agree," and 5 representing "strongly agree." Example questions from the MTEBI include "I understand mathematics well enough to be effective in teaching math"; "Even when I try very hard, I don't teach mathematics as well as I do most subjects"; and "I find it difficult to use manipulatives to explain why mathematics works" (Enochs et al., 2000).

Procedures

To begin this case study, the gatekeeper organized a meeting with the master teachers before the school year began so the researcher could go over the purpose and details of the study and explain the Informed Consent Form (Appendix I). The potential participants were informed that there would be no penalties if they decided not to sign the Informed Consent Form and declined to participate in the study. All but one master teacher signed the Informed Consent and agreed to participate in the study.

The gatekeeper then organized a meeting with the student teachers at the beginning of the student teaching assignment so the researcher could go over the purpose and details of the study and explain the Informed Consent Form (Appendix J). The potential participants were informed that there would be no penalties if they decided not to sign the Informed Consent Form and declined to participate in the study. All of the student teachers signed the Informed Consent and agreed to participate in the study.

After obtaining informed consent, the researcher met with the student teacher participants to go over the timeline and expectations for the study. As part of their student teaching course assignments, each student teacher created lesson plans with reflections and completed peer coaching forms multiple times throughout the year with their partner student teacher to refine their teaching skills. Those documents were turned into their university supervisor as part of their student teaching course assignments. The university supervisor then made copies of the participating student teachers' documents/assignments without their names on them to give to the researcher at the end of each semester.

In fall and again in spring 2014, each student teacher videotaped themselves teaching a STEM lesson as part of their student teaching course requirements. The student teachers completed a self-evaluation form to reflect on their lesson and included student work. The student teachers also included in their reflection how the STEM professional development supported the teaching of their lesson. The student teachers turned in their lesson and reflection from the fall to their university supervisor to give a copy to the researcher. In spring, the student teachers gave a copy of the videotaped lesson, the lesson plan, student work, and the reflection to their university supervisor to give a copy to the researcher to watch and analyze the videotaped lesson and accompanying documents.

In spring of the 2013–2014 school year, the student teachers were interviewed individually to learn about the their perspectives of the STEM-rich, clinical, co-teaching model of student teaching as well as their feeling of preparedness to enter the teaching profession. The semi-structured, open-ended interviews lasted approximately 45 minutes. All except for one student teacher was interviewed. The student teacher that was not interviewed did not complete the student teaching program and exited from the program before the interviews took place.

In spring of the 2013–2014 school year, the master teachers were interviewed in a focus group consisting of two teachers that taught the same grade level. The fifth grade master teachers were interviewed together, as were the second grade master teachers. However, the transitional Kindergarten master teacher was interviewed individually because she was the only master teacher at her grade level that participated in this study. The semi-structured, open-ended interviews lasted approximately 45 minutes. The purpose of the interview was to learn about the master teachers' perspectives of their student teachers' progress towards effectively teaching STEM content at the conclusion of the STEM-rich, clinical, co-teaching model of student teaching.

Additionally, all student teachers who participated in the grant-funded STEM professional development, not only the student teachers from Seaside Elementary School, completed the pre- and post-surveys to measure any changes in their self-efficacy in teaching science and mathematics. The pre-survey was administered at the first STEM-rich professional development session in September 2013 and the post-survey was given at the final STEM-rich professional development session in May 2014. The STEBI quantitatively measures the student teachers' efficacy beliefs in science teaching, while the MTEBI quantitatively measures the student teachers' efficacy beliefs in mathematics.

Timeline

The duration of this case study was the 2013–2014 academic school year. The various data sources were collected throughout the school year at different times in fall and spring. The STEM professional development sessions were held throughout the 2013–2014 school year. Figure 4 is a timeline that summarizes the on-going STEM professional development and when the multiple data sources were collected during this case study.

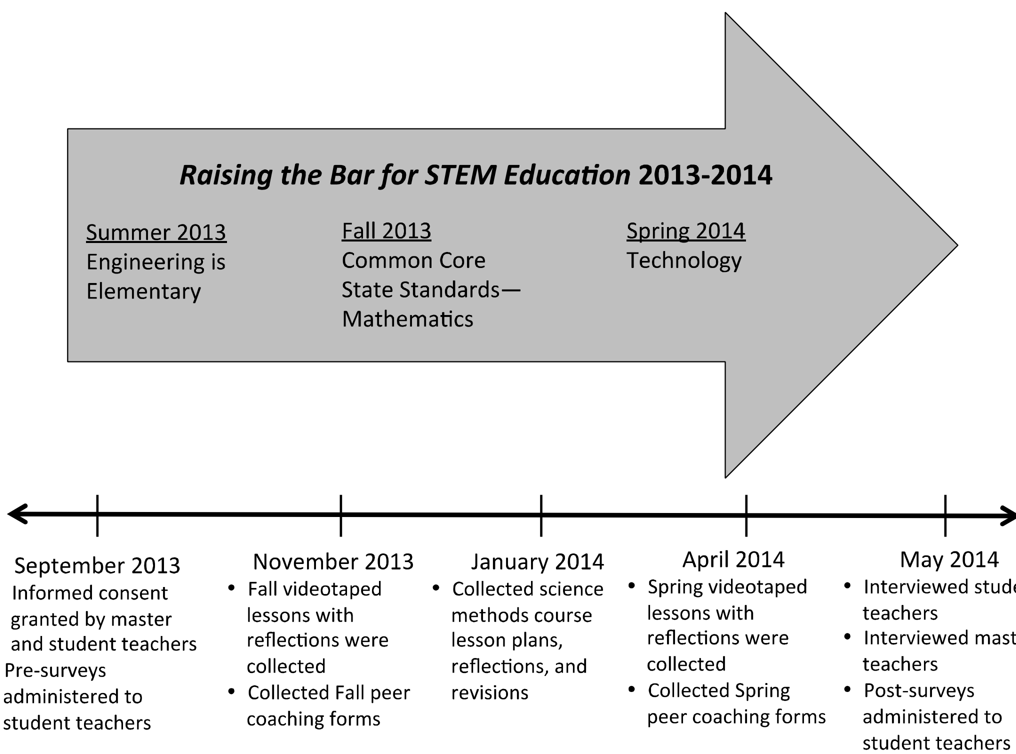

FIGURE 4. Timeline of the STEM-rich professional development and data collection methods throughout the 2013–2014 academic school year.

Data Analysis

In case study research, data analysis occurs informally throughout the study, not just at the conclusion of data collection. Yin (2014) states, "case study research requires an inquiring mind during data collection, not just before or after the activity" (p. 73). To do this, the researcher kept a research log and recorded analytical memos throughout this case study to record her insights throughout data collection process and during data analysis.

Qualitative Data Analysis

At the conclusion of the 2013–2104 school year, the formal data analysis process began by inputting all data sources, including analytical memos, into the computer-assisted qualitative data analysis software NVivo to create a case study database (Bazeley & Jackson, 2013). This case study database helped the researcher organize all of the data collected and was used throughout the analysis process. The researcher began the process of analyzing the data by looking for patterns, insights, or categories that seemed interesting by creating various data displays within NVivo (Bazeley & Jackson, 2013; Yin, 2014). This preliminary analysis assisted the researcher in interpreting and conceptualizing the data before coding.

The researcher then immersed herself into the data by reading and rereading the transcribed interviews and other data sources multiple times. Saldaña (2013) states that any and all data that have been collected should be coded during the data analysis process. "Coding consists of creating a label or title for a chunk of text that captures its meaning. . . . The idea of coding is to begin to decontextualize these texts into meaningful chunks of coded materials" (Hesse-Biber & Leavy, 2011, p. 270).

As recommended by Saldaña (2013), multiple cycles of coding were used throughout the analysis process. Before the first cycle of coding began, the researcher created a list of 25 potential codes based on the research questions, interview protocols, literature, and conceptual framework. Some of the codes were "confidence," "peer coaching," "engaging students," and "linking professional development to teaching." Additional codes were added as they emerged from the data. Some of the codes added were "communication" and "higher order questioning." During the first cycle of coding, the researcher chose to code all data sources one code at a time so that she could immerse herself in the data by focusing on each code individually; this enhanced consistency throughout the coding process. The researcher also wrote analytical memos to record connections of the data to the literature and questions that arose during coding. At the conclusion of the first cycle of coding, there were a total of 36 codes.

During the second cycle of coding, codes that were similar to other codes were collapsed into one code. For example, "partner student teacher" and "interactions with partner student teacher" were consolidated into one code called "student teaching partner." During this cycle of coding, codes were also eliminated if they did not have enough substance. For example, the code "grant-funded" was only used two times during the first cycle of coding, so it was removed because it was not significant enough to include in the findings. All codes with less than 10 references were excluded. The second cycle of coding concluded with a total of 23 codes.

In continuing the cycles of coding, the researcher looked at the magnitude of each code to identify codes that occurred more frequently than others, because this implied that certain codes were more significant than others. The codes that occurred more frequently were analyzed more deeply by connecting them to the literature and the conceptual framework. The researcher created a table that listed each of the codes with quotes and evidence from the data to determine which codes were data light and needed to be disregarded. Codes were kept in a code notebook and the various cycles of coding were documented.

Next, the matrix coding function in NVivo was used to see how the codes interacted with one another (Bazeley & Jackson, 2013). This is where the themes began to emerge. The researcher then wrote each remaining code onto a notecard and used the notecards to move around into groups to assist in forming themes. In identifying themes, the researcher looked for distinctions across themes as well as depth and richness within each theme. The themes that emerged answered the research questions and created a story that described the student teachers' experiences in their STEM-rich, clinical, co-teaching model of student teaching.

Additionally, an analytic technique called "time-series analysis" was used to analyze the data. When using a time-series analysis, the researcher compiled the data into chronological order to look for patterns and themes over time, which is one of the major strengths of a case study (Yin, 2014). The time-series analysis technique enabled the research to discover a theme that was not specifically coded for in the initial data analysis process: the growth and maturation of the student teachers throughout the yearlong student teaching program.

At this point, there were nine themes: advantages and disadvantages of co-teaching; best and worst of STEM professional development; linking professional development to classroom practice; Common Core impacts the yearlong professional development; support is critical; mathematics and science superseded technology and engineering; growth and maturation of student teachers throughout the year; uneven growth of confidence; and uneven growth of content knowledge. In order to continue to consolidate the themes into meta-themes that painted a more complete and holistic picture about the STEM-rich, clinical, co-teaching model of student teaching while answering the research questions, the researcher went back to the data to continue to look for patterns across the data and to triangulate the findings within each theme. Additionally, the researcher identified exemplars within the data and created posters to visually display the big ideas for each theme. This visual representation of the findings helped the researcher realize how the themes overlapped and interacted with one another to tell the story of the student teachers' experiences. The researcher concluded the data analysis process by consolidating the nine themes into four themes: strengths of the STEM-rich professional development; weaknesses of the STEM-rich professional development; strengths and weaknesses of the clinical, co-teaching model of student teaching; and impact of CCSS on the STEM-rich, professional development.

Throughout the data analysis process, the researcher used peer debriefing to get a second opinion and an endorsement of the analysis. The researcher also consulted with her dissertation chair throughout the process of data analysis. To ensure that the data analysis is of the highest quality, the researcher followed the guidelines presented by Yin (2014). The researcher made sure to utilize all of the evidence presented in the various data sources without leaving any unanswered questions. The researcher also strived to address all possible rival interpretations of the findings and used her own expert knowledge in the field when analyzing the data (Yin, 2014).

Quantitative Data Analysis

The pre- and post-survey data from the STEBI and MTEBI was analyzed using a paired samples *t*-test to test for differences between related means from the pre-survey to the post-survey (Yockey, 2011). The null hypothesis was that there was no difference between the student teachers' self-reported self-efficacy mean score from the pre-survey to the mean score of the post-survey given at the completion of the STEM-rich student teaching program. The alternative hypothesis was that there was a difference between the student teachers' self-reported self-efficacy mean score from the pre-survey to the mean score of the post-survey. Significance was determined by a *p*-value less than .05. Effect size was found utilizing Cohen's (1988) standard of dividing the mean difference by the standard deviation of the difference scores.

Protection of Participants

The researcher submitted the research plan to the CSULB Institutional Review Board (IRB) to review the plan before the research was conducted. The request for research was approved by IRB for human subject research. Additionally, informed consent was obtained from each particiapnt prior to the beginning of the research study and data collection. The informed consent informed participants of the purpose of the research study, procedures and expectations of the study if they chose to participate, explanation of any risks associated with the research, and information about their right to withdraw from the study at any time without any consequences.

There were no major risks or hazards for participants in this research. However, the potential risks to the participants included feeling uncomfortable answering specific questions during the interviews and facing professional risk by being embarrassed by a perception that they may be revealing a lack of STEM knowledge during the interviews and/or document analysis. Additionally, student teachers may have worried about their lack of experience teaching, and participants may have worried about their confidentiality during interviews and with their documents/videos (lesson plans, journal reflections, peer coaching forms, videotaped lesson).

The researcher made every effort to explain to participants that she was aware that student teachers have not been trained heavily in STEM disciplines and teaching strategies, and that the purpose of the STEM-rich, clinical, co-teaching model of student teaching was to improve the teaching of STEM content and to prepare future elementary teachers. Additionally, participants were reminded that they could refuse to answer any interview question and/or remove themselves from the study at any time.

The research site was given a pseudonym to promote confidentiality. The university supervisor collected lesson plans, journal reflections, and peer coaching forms from the student teachers and removed their names before giving them to the researcher to enhance confidentiality. The data was kept on a password-protected computer in the researcher's home.

Trustworthiness

To heighten the trustworthiness for methodological rigor in this study, the researcher maintained a research log to document the research process and provide an audit trail. Additionally, collecting and analyzing multiple sources of data to answer the research questions triangulated the data sources and findings. The researcher kept a coding notebook to document the coding process and coding cycles during data analysis. During the data analysis process, the researcher involved peer debriefers and asked an external expert for her input to endorse the data analysis and findings. Additionally, the following positionality statement builds transparency and credibility in the researcher.

Positionality

A reason that the researcher chose to research the impact of the Raising the Bar for STEM Education in California program on preparing student teachers to effectively teach STEM subjects is because she received a fellowship to study the program and is therefore interested in its effectiveness and impact. The researcher's fascination in the STEM-rich teacher preparation program derives from her background as a middle school algebra teacher and experiences transitioning from teaching elementary grades to middle school. The researcher's biases are based on her 8 years of experience as a mathematics teacher. Additionally, the researcher earned her multiple subject teaching credential through a program similar to the Raising the Bar for STEM Education in California program's clinical model of student teaching from CSULB, but without the STEM focus. The researcher then took additional classes at CSULB to earn a supplemental credential to teach middle school mathematics. This experience parallels those student teachers in the Raising the Bar for STEM Education in California program, which prompted the researcher's interest in exploring the student teachers' perceptions of the program and its impact on preparing future elementary teachers to effectively teach STEM subjects.

The researcher's personal experiences and biases could have affected the way she analyzed the data. However, the researcher kept a detailed research log to document the research process and the choices she made throughout the study to combat her biases. Sharing the researcher's positionality about the research topic, experiences, and biases demonstrates transparency and builds credibility.

Conclusion

The primary purpose of this study is to assess the effectiveness of a yearlong intensive STEM-rich professional development and teacher preparation program in preparing future elementary teachers to effectively teach STEM content. A grant from the S.D. Bechtel Jr. Foundation required investigators to measure the effectiveness of this STEM-rich, clinical, co-teaching model of student teaching.

A single-case study design utilizing qualitative and quantitative methods explored how the STEM-rich, clinical, co-teaching model of student teaching prepares future elementary teachers to effectively teach STEM content. This study also investigated the impact of the implementation of CCSS on the STEM-rich, clinical, co-teaching model of student teaching. This yearlong case study used interviews, videotaped lessons, lesson plans with reflections, peer coaching documents, and pre- and post-survey data to learn about the experiences of student teachers in the program.

Chapter 4 will present the findings of this case study.

CHAPTER 4

FINDINGS

The purpose of this case study was to explore the experiences of elementary student teachers in a STEM-rich, clinical, co-teaching model of student teaching to learn how the program prepared them to effectively teach STEM content. Additionally, the goal of this research was to discover how the implementation of CCSS impacted the STEM-rich, clinical, co-teaching model of student teaching. This study was guided by the following research questions:

1. How did the STEM-rich, clinical, co-teaching model of student teaching prepare student teachers to effectively teach STEM content?

2. How did the implementation of the educational reform effort for the Common Core State Standards impact the STEM-rich, clinical, co-teaching model of student teaching?

A case study was conducted during the 2013–2014 school year at Seaside Elementary School in a large, urban public school district in Southern California to learn how the STEM-rich clinical, co-teaching model of student teaching prepared student teachers to effectively teach STEM content and how the implementation of CCSS impacted the STEM-rich program. Various data sources, including qualitative and quantitative data, were collected over a yearlong period to analyze for this study. Participants included 10 student teachers, five master teachers, and one university supervisor.

Findings

The data collected for this case study included interviews with student teachers and master teachers, lesson plans, videotaped lessons, reflections on lessons, journal entries, peer coaching forms, student work, and pre- and post-survey data. The qualitative data sources were analyzed using multiple cycles of open coding until several themes emerged. The quantitative pre- and post-surveys were analyzed using a paired samples *t*-test. The following overarching themes address the research questions guiding this study and paint a picture of the STEM-rich, clinical, co-teaching model of student teaching:

1. Strengths of the STEM-rich professional development.
2. Weaknesses of the STEM-rich professional development.
3. Strengths and weaknesses of the clinical, co-teaching model of student teaching.
4. Impact of Common Core State Standards on the STEM-rich, professional development.

Each theme will be addressed in this chapter along with sub-categories to illustrate the experiences of the student teachers in the STEM-rich, clinical, co-teaching model of student teaching and to identify components of the STEM-rich professional development that prepared the student teachers to effectively teach STEM content. Additionally, the themes will be linked to the research questions in order to paint a holistic picture of the student teachers' experiences.

Strengths of the STEM-Rich Professional Development

Because the majority of teacher preparation programs in California do not specifically address STEM content and teaching practices at the elementary level, CSULB implemented a grant-funded STEM-rich teacher preparation program called Raising the Bar for STEM Education: Preparing Elementary Teachers in a Model, Scalable, STEM-Rich Clinical Setting. The goal of the yearlong STEM-rich teacher preparation program was to develop future elementary teachers' content knowledge and pedagogical strategies in teaching STEM content. To meet the objectives of the grant, CSULB partnered with a local school district to provide ongoing, in-depth professional development in STEM for student and master teachers in the UTEACH program. The UTEACH program is a clinical, co-teaching model of student teaching. This STEM-rich professional development program was offered in addition to the methods courses and student teaching experiences.

During the yearlong STEM-rich professional development, student teachers attended a 4-day Summer Institute focused on connecting engineering to science utilizing EiE curriculum from the Boston Museum of Science. Six additional days of STEM-rich professional development occurred throughout the 2013–2014 school year. In total, student teachers received 60 hours of STEM-rich professional development, including the Summer Institute and evening sessions during the school year. The STEM-rich professional development sessions were held monthly afterschool from 3:30 p.m. to 7:00 p.m. All of the student and master teachers in the UTEACH program attended the afterschool professional development sessions. Three of the evenings sessions focused on mathematics, while the other three sessions focused on technology. Some of the topics addressed in the professional development were the Engineering Design Process, Common Core State Standards—Mathematics, NGSS, utilizing technology to support STEM subjects, developing and sequencing STEM units, writing inquiry based lessons in the 5E format for science (Appendix E), and incorporating student discussions in mathematics. Figure 5 shows pictures from a professional development session aimed at learning how to develop and sequence science units using a conceptual model focused on essential understandings from the grade level they teach.

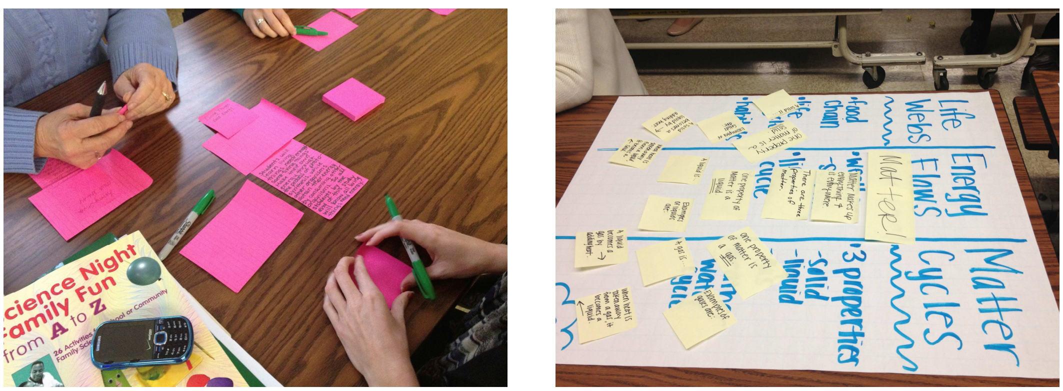

FIGURE 5. Pictures from the STEM professional development.

The STEM-rich professional development benefited the student teachers in many ways that were evident in the data. Student teachers developed theoretical understandings of instructional practices for teaching STEM subjects, connected and applied the theory learned in the STEM-rich professional development to practice, and increased their confidence in teaching science and mathematics. Elements of the design and implementation of the STEM-rich professional development program that incorporated principles of adult learning theory benefited the student teachers' learning of theory and practical applications of STEM content.

Theoretical understanding of teaching STEM. The STEM-rich professional development focused primarily on pedagogical strategies for teaching STEM content. In the interviews with the student teachers, they described learning from the professional development that STEM should be hands-on, investigative, inquiry-based, and student-centered. Student teachers explained the importance of building students' conceptual understanding, asking students higher-level questions, engaging students through inquiry, and focusing on problem solving when teaching STEM. One student teacher described the theoretical foundation of STEM as: "STEM is science, technology, engineering, and mathematics with the focus on investigative, student-centered, hands-on learning where students get to explain why and how and they're not given the information."

Exploring and investigating concepts in science, technology, engineering, and mathematics is critical to help students reach a level of understanding of ideas central to the subject, not memorizing facts or following step-by-step procedures. A student teacher described how the STEM professional development helped build her theoretical understanding of teaching mathematics by stating: "In our STEM trainings we do talk a lot about asking the why's. Asking the how's, versus just procedural steps, having them explain to us why, having students rephrase why."

Enhancing the student teachers' understanding of instructional practices for teaching STEM subjects impacts their PCK in STEM subjects. PCK requires teachers to be strong in both pedagogy and content knowledge in the subjects that they teach. For the student teachers to have strong PCK in STEM content areas, they need to learn about content and pedagogical strategies for teaching STEM subjects. The data reveal that the STEM-rich professional development positively impacted the student teachers' knowledge of pedagogical strategies for teaching STEM subjects.

One characteristic of the professional development that facilitated the student teachers' learning of theoretical best practices for teaching STEM content was the time for collaboration with master teachers and other student teachers. This created a network of people, both student teachers and master teachers, who helped each other expand their own understanding of STEM disciplines and learn about best practices for teaching STEM throughout the yearlong professional development. Learning from the experiences of others was beneficial, many of the student teachers reported in their interviews. One student teacher explained how collaborating with master teachers benefited her:

> I would listen to the older teachers that had more experience. They had been in that classroom for so many years, so listening to them talk about how they have approached [teaching STEM] or how they would approach it. I would take notes from that because they had experience with their classrooms. I think that was the beneficial part.

Collaborating with others connects to adult learning theory because it builds upon the principles of orientation to learning and motivation (Knowles, 1980; Miroballi, 2010). Gomez (2012) explains that adult learners "must have purpose in what they are learning. Learners must understand how this learning experience will help them solve a problem or complete a future task" (p. 42). When the student teachers were able to collaborate with master teachers and other student teachers, they had a purpose for learning. Learning from the experiences of teachers who have taught for many years helped student teachers understand how their learning of STEM is applicable and gave them motivation to learn.

Active learning was another component of the STEM professional development that helped the student teachers learn about the theoretical underpinnings of STEM teaching and learning. One of the professional development sessions incorporated the use of centers so the student teachers rotated through different STEM stations that incorporated science, mathematics, and engineering. This activity helped the learning process because the student teachers felt like a student themselves and were engaged, hands-on learners during the professional development. One student teacher reported:

> Well in STEM you do realize because you get to participate in it, so you get to be the student, and then you get to be the teacher. So you do get both perspectives and you do realize, well, if I'm doing this hands on, not only am I learning, but I'm also creating what I'm doing, and so it's beneficial. So I do like that, you have both lenses.

Active learning connects to adult learning theory because adults learn best when they are actively engaged in their learning and when the learning activity is focused on their experiences (Gomez, 2012; Knowles, 1980; Miroballi, 2010). Thus, adult learning theory describes effective learning environments for adults, and active learning is one of its principles. By designing the STEM-rich professional development so the student teachers are learning about STEM through an active, hands-on approach rather than lecturing about learning STEM, the student teachers gain a deeper understanding of STEM. This deeper understanding of STEM enabled student teachers to develop a robust understanding of the theoretical philosophy of STEM, which includes a problem solving, critical thinking, and investigative approach to teaching STEM subjects.

Connecting theory to practice. The information learned from the STEM-rich professional development that was applied in the classroom by the student teachers was mostly in mathematics and science. Student teachers described teaching STEM as "fun" and that it allowed them to be more “creative” and “think outside of the box” when lesson planning. Data from the interviews with student and master teachers, lesson plans, and the videotaped lessons revealed that student teachers tried to engage students through the use of inquiry, which was one of the key principles taught in the STEM-rich professional development. An example of a creative science lesson in a second grade class was described in one student teacher’s journal. She explained that the students acted as engineers and explored how adding weight impacted simple tools and machines. Another student teacher wrote a reflection on a transitional Kindergarten science lesson in her journal:

> The STEM PD nights are very much about learning through exploring. I let my students use pinwheels and asked what they noticed about the pinwheels movement in comparison to the wind strength. They learned by exploring. Students were engaged and active for the lesson, especially during the pinwheel section. Having realia helped make the concept of measuring wind become concrete and real.

These activities used by the student teachers with their students are examples of application of the professional development. Several of the student teachers’ lesson plans replicated activities done in the STEM-rich professional development sessions.

Another example of applying what was learned in the STEM professional development to classroom practice was the use of the 5E lesson plan (Appendix E) by the student teachers. The 5E lesson plan is a well-researched, commonly recognized lesson plan used in science to develop students’ scientific reasoning and encourage interest and positive attitudes towards science (Bybee et al., 2006). The 5E lesson plan is endorsed and recommended by the National Science Teachers Association (NTSA) to use for teaching NGSS and the Science and Engineering Practices (Bybee, 2013). The 5E lesson plan was introduced in the STEM-rich professional development as a structure for designing inquiry-based, student-centered lessons. The science methods course also emphasized the use of the 5E lesson plan when writing lessons to help student teachers engage their students in all grade levels as well as foster interest in science content. Figure 6 displays the components of the 5E lesson plan.

5E Lesson Plan

Engage: Capture students' interests

Explore: Hands-on/minds-on activities

Explain: Students explain their exploration activity

Elaborate: Develop a deeper understanding of content

Evaluate: Students demonstrate their understanding

FIGURE 6. 5E lesson plan.

The 5E lesson plan was used by all student teachers throughout their student teaching experience, according to collected lesson plans, reflections, peer coaching forms, and self-reported interview data. All of the student teachers described the 5E lesson plan as a useful tool they learned from the STEM professional development and from their science methods course. This was a direct take-away from the professional development sessions that was applied frequently by the student teachers. Using this lesson plan structure helped the student teachers design hands-on, engaging, inquiry-based lessons for their students when teaching science. One student teacher reported: "The 5E lesson plans, I think those are all really beneficial for me to see and learn about. It's all about being investigative. Those how, why questions." All of the science lesson plans collected were written in the 5E lesson plan format. Lesson planning is an overall strength for the student teachers. In the interviews, the student teachers explained that they felt they have grown in the area of lesson design due to the 5E lesson plan. The use of the 5E lesson plan is an example of how the STEM-rich professional development enhanced student teachers' PCK in teaching science and other STEM content areas.

Additionally, student teachers connected theory about STEM to classroom practice by focusing on conceptual understanding and asking "how" and "why" questions rather than only on memorizing procedures when teaching STEM subjects. This was apparent in the science and mathematics lesson plans, journal entries, reflections, and the videotaped lessons. For example, in one reflection on a videotaped lesson, a student teacher described the focus on conceptual understanding in her science lesson by writing "good questions were asked, discovered, and answered." Additionally, the student work samples collected demonstrate K–5 students' conceptual understanding of mathematics at various grade levels through the use of multiple representations. Figure 7 is a picture of a transitional Kindergarten student's work in mathematics learning about the fact family 8 + 1 = 9. This student work sample conforms to the Common Core Standards for Mathematical Practice in that the student is conceptualizing an addition fact family in multiple ways, including pictures, tally marks, and several different equations.

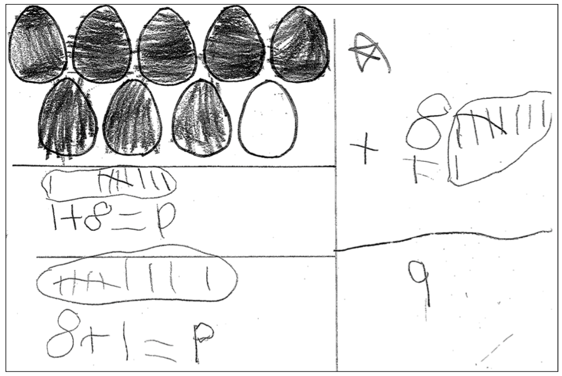

FIGURE 7. Picture of student's work in mathematics.

This picture is an example of using multiple representations to build conceptual understanding of addition and exhibits how some of the student teachers connected theoretical understandings about instructional strategies for teaching STEM to practice in the classroom during their student teaching.

Furthermore, Family STEM Night was a success. Activities from the STEM-rich professional development were used by the student teachers when planning the Family STEM Night. These engaging, hands-on activities were replicated with parents, family members, students, and community members. The purpose of this event was to involve the community with the school's focus on STEM. Family STEM Night was fun and engaging for all who attended. Figure 8 includes pictures from the Family STEM Night hosted and organized by the student teachers based on their learning from the STEM-rich professional development.

Applying their learning from the STEM-rich professional development to Family Science Night contributed to growth in the student teachers' confidence and PCK in teaching STEM.

FIGURE 8. Pictures of Family STEM Night.

Although student teachers focused mostly on mathematics and science, not engineering and technology, when applying the STEM-rich professional development to the classroom, the data collected revealed multiple examples of connecting theory to practice. This ties to adult learning theory because adults' learn best if their learning is connected to practice (Knowles, 1980; Miroballi, 2010). Because the goal of any professional development is to impact teachers' practice, the examples of how the student teachers applied the theory they learned in the STEM-rich professional development to practice is a strength of the professional development.

<u>Increased confidence to teach STEM subjects</u>. Student teachers completed a pre- and post-survey to measure their self-efficacy beliefs in teaching science and mathematics. The Science Teaching Efficacy Beliefs Instrument, or STEBI (Riggs &

Enochs, 1990), and the Mathematics Teaching Efficacy Beliefs Instrument, or MTEBI (Enochs et al., 2000), were given to all 38 student teachers in the Raising the Bar professional development program, not only the student teachers at Seaside Elementary School, as the pre- and post-surveys to measure growth of self-efficacy from before the STEM-rich professional development to after.

Of the 38 student teachers that took the STEBI, only 25 completed both the pre-survey and the post-survey in its entirety. Therefore, only the 25 complete surveys were included in the analysis. The PSTE portion of the STEBI was analyzed using a paired samples *t*-test. Table 4 displays the output of the paired samples *t*-test for the PSTE of the STEBI.

TABLE 4. STEBI Paired-Samples *t*-Test Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PreSciencePSTE	47.24	25	5.04	1.01
	PostSciencePSTE	55.52	25	5.86	1.17

Student teachers' personal science teaching scores on the PSTE portion of the STEBI were significantly higher at the end of the yearlong STEM-rich professional development (M = 55.52, SD = 5.86) than at the beginning of the STEM-rich professional development (M = 47.24, SD = 5.04), $t(24) = 6.56$, $p < .05$, $d = 1.31$. The effect size, d, was determined by dividing the mean difference by the standard deviation of the difference scores: $d = \frac{8.28}{6.31} = 1.31$ (Yockey, 2011). This is considered a large effect size by Cohen's (1988) standards.

Likewise, of the 38 student teachers that took the MTEBI, only 26 completed both the pre-survey and the post-survey and were included in the analysis. Using a paired samples *t*-test, the PTME portion of the MTEBI was analyzed to measure potential growth from the pre-survey to the post-survey. Table 5 displays the output of the paired samples *t*-test for the PTME of the MTEBI.

TABLE 5. MTEBI Paired-Samples *t*-Test Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PreMathPTME	52.23	26	5.38	1.05
	PostMathPTME	57.42	26	4.88	0.96

Student teachers' personal mathematics teaching scores on the PTME portion of the MTEBI were significantly higher at the end of the yearlong STEM-rich professional development (M = 57.42, SD = 4.88) than at the beginning of the STEM-rich professional development (M = 52.23, SD = 5.38), $t(25) = 5.83$, $p < .05$, $d = 1.14$. The effect size was large by Cohen's (1988) standards and was determined by dividing the mean difference by the standard deviation of the difference scores: $d = \frac{5.19}{4.54} = 1.14$ (Yockey, 2011).

The pre- and post-surveys reveal that student teachers' personal self-efficacy in teaching science and mathematics increased from the beginning of the STEM-rich professional development to its end. Confidence is a concept embedded in the theoretical construct self-efficacy. Additionally, self-efficacy connects to the self-concept principle in adult learning theory (Knowles, 1980; Miroballi, 2010). As such, the pre- and post-surveys provide evidence that the student teachers' confidence in teaching science and mathematics increased by the conclusion of the STEM-rich professional development program.

Building on the quantitative survey findings, many student teachers reported that they were confident in teaching mathematics and science at the completion of their student teaching experience. This may be due to learning about specific strategies for teaching mathematics and science, including writing effective lesson plans, during the professional development sessions. One student teacher reported:

> I feel like for science I was really un-confident in the beginning of the year because I thought science was really hard and not my subject, but after STEM I really liked science and they've helped me grow and they've helped me really understand how to make the lesson plan and how to develop it. So my confidence for science has really grown.

Additionally, exposure to engineering and resources for incorporating technology during the professional development sessions strengthened the student teachers' confidence. One student teacher reported:

> So I think that engineering night that we had one of the first STEM PDs, it reminded me of how many things actually are engineering, and that it doesn't have to be a scary mathematical type thing. It's actually just hands on—design something, change it, make it work—which was nice.

Most of the student teachers revealed their excitement about teaching STEM and their willingness to try new things in their classroom. Validation from their master teacher, partner student teacher, and university supervisor boosted the confidence of the student teachers and influenced their enthusiasm and disposition towards teaching STEM subjects.

This connects to my conceptual framework because PCK and adult learning theory are critical for improving student teachers' confidence in teaching STEM subjects.

PCK explains that teachers need to be strong in both pedagogy and content knowledge in order to be an effective teacher (Shulman, 1986). In relating this to the STEM-rich professional development, student teachers who reported that their confidence increased credited the professional development program for both introducing them to STEM content and focusing on effective instructional strategies for teaching STEM. Additionally, as the student teachers' confidence increased, their self-concept altered to believing they can teach STEM content effectively; this is a key principle of adult learning theory.

Moreover, a growth mindset was evident for most of the student teachers (Dweck, 2006). They were confident in their ability to apply what they learned from the STEM-rich professional development to their own classroom once they complete their teacher preparation program and enter the field. Student teachers with a growth mindset believed that they will be able to continue to learn and refine their STEM teaching practices.

Because student teachers concluded their student teaching program with a solid theoretical understanding of instructional practices to effectively teach STEM subjects and an increase in confidence to teach STEM, they are prepared and ready to enter the field STEM-focused. The goal of the Raising the Bar for STEM Education in California program was to create a pipeline of highly qualified STEM elementary teachers. The self-reported data, as well as the evidence collected, point to the notion that the student teachers are willing and likely to teach STEM content in their future classrooms.

Weaknesses of the STEM-Rich Professional Development

Although there were many strengths of the STEM-rich professional development, several weaknesses surfaced through data analysis. While the student teachers increased their confidence and knowledge of the theoretical foundation of instruction for STEM, the growth was uneven among the STEM content areas. Specific aspects of the professional development program were not as impactful as others. Lack of integration of the STEM areas hindered the student teachers' application of STEM. Additionally, some student teachers missed the overall rationale of the importance of STEM and its implication for students and society.

Uneven growth of confidence and skills in STEM areas. Although the student teachers increased their confidence in teaching STEM subjects and developed a strong theoretical understanding of teaching STEM content during their yearlong student teaching program, further analysis discovered an uneven growth amongst the STEM content areas. Science and mathematics in STEM superseded technology and engineering in increasing student teachers' confidence and instructional strategies; thus, student teachers reported more growth in science and mathematics than in technology and engineering. One student teacher explained, "I don't think I worked very much with engineering and technology but I think I can benefit from, I don't know, practicing it a little bit more." This may be due to the fact that more time was spent on science and mathematics in the professional development sessions than on technology and engineering. Another student teacher reported:

> I feel the engineering part is probably where I'm weakest and that's probably because I haven't conducted any lessons with engineering. The technology part I feel I do have some familiarity with the technology. In my own personal use, I feel like I could incorporate that into my teaching later on. It isn't necessarily a strength, but I don't consider it a weakness either. I feel that would be much easier to grasp, since I do have some background knowledge with that, but the engineering would probably be my weakest.

All of the student teachers and master teachers reported in their interview that they felt more comfortable and confident in science and/or mathematics compared to technology and engineering. Additionally, all participants stated that they wanted to learn more about technology and engineering. This uneven growth in confidence represents an uneven growth of PCK as well with student teachers feeling that they need to learn more content and pedagogical strategies for teaching engineering and technology.

Another contributor to the uneven growth of confidence and pedagogical strategies in teaching STEM was that student teachers did not apply their learning of engineering and technology from the STEM-rich professional development to their student teaching. Several student teachers explained that this lack of application is because engineering and technology are not typically taught in the elementary classrooms. This connects to the literature (Weiss et al., 2001). As a result, student teachers felt like they could not incorporate some of their learning from the professional development into the classrooms and keep up with the current curriculum. One student teacher explained:

> I didn't see an opportunity to incorporate [engineering] in my teaching of second grade. I feel like I could later on if I had my own classroom where I could design what I'm teaching, but since I followed my master teachers' plans and where we need to go we hadn't hit the engineering part.

Incorporating aspects of STEM outside of science and mathematics was not in the master teachers' plans because it was not built into the district recommended curriculum. As such, student teachers did not have the opportunity to teach engineering or technology frequently so they did not get enough practice to build PCK in these areas. Although all of the student teachers had the opportunity to teach science and apply their learning from the STEM-rich professional development, they reported that it was sporadic and infrequent. Mathematics was the only area of STEM that was described as being taught often by the student teachers throughout their student teaching program. Other data, such as lesson plans, reflections on taught lesson plans, videotaped lessons, and peer coaching forms, triangulated this finding that student teachers had the opportunity to teach mathematics often and science occasionally, while engineering and technology was virtually nonexistent. A few student teachers tried to integrate aspects of engineering and technology into their lessons in other content, but many did not. Thus, the student teachers' growth in confidence and skills to effectively teach STEM subjects was uneven; "S" and "M" surpassed the "T" and "E."

Specific aspects of the professional development. Student teachers stated that the engineering aspect of the professional development during the Summer Institute was the most engaging, exciting, and meaningful compared to the rest of the professional development. Many student teachers described the technology nights as informative and interesting. Conversely, the structure of the mathematics portions of the professional development left much to be desired. Participants recounted that during the mathematics nights of the professional development they were shown videos that were out-of-date and studied the new Common Core Standards instead of learning about exemplar lessons or engaging activities they could replicate with their students. Participants explained that they would have liked grade-level specific activities and sample lessons for mathematics. One student teacher reported:

> I think the math could have had more examples of how to teach a really good math lesson. I liked the videos and the paper work and everything but since math

> is so different than how I was taught just . . . even like them doing a lesson and having us be like the kids would have been really helpful.

Unfortunately, the student teachers did not take away as much about teaching mathematics as they did the other subjects during the professional development because of the lack of application of mathematics directly to the classroom. This is unfortunate because mathematics was the subject most frequently taught by the student teachers while student teaching, but not the subject with the most takeaways from the STEM-rich professional development.

This connects to adult learning theory because adult learners need to connect their experiences and be internally motivated when learning (Knowles, 1980; Miroballi, 2010). The mathematics part of the professional development was not engaging and, as such, did not motivate the student teachers. Additionally, because the focus of the mathematics portion was on studying the standards, not on examples of effective mathematics lessons or how to plan mathematics lessons based on the principles of CCSS, the student teachers were not immediately able to apply their learning, which adult learning theory describes as imperative for adult learners. Because the mathematics portion of the professional development did not align to the principles of adult learning theory, it explains why it was the least successful aspect of the professional development.

<u>Lack of integration</u>. The STEM-rich professional development was designed to divide the four areas of STEM evenly throughout the yearlong professional development program, so student teachers would learn about each component with the same intensity. Accordingly, each aspect of STEM was taught during separate nights in order to focus on one subject at a time. The organizers and providers of the professional development for

each subject of STEM did not coordinate or collaborate. Consequently, the topics of the STEM-rich professional development did not emphasize nor model the integration of the STEM subjects. Because of this lack of integration in the professional development, student teachers focused on teaching each STEM content area in isolation from each other, even though STEM lends itself to integration. This connects to Hoachlander and Yanofsky's (2011) findings that in practice "STEM tends to function in isolation from other core subjects" (p. 2). Instead of describing the integration of STEM subjects, student teachers described STEM as "teaching science effectively" or "teaching mathematics effectively."

This is critical because the "an interdisciplinary approach to STEM instruction" is grounded in its integration, not in each individual component. Californians Dedicated to Education Foundation (2014) further explains that STEM is an "interdisciplinary and applied approach that is coupled with real-world, problem-based learning" (p. 7). The purpose of an interdisciplinary approach is two-fold: To make the teaching of STEM subjects feasible in elementary school given the limited time available and to give students a better understanding of how the separate disciplines integrate in real-world fields, such as medicine, engineering, and product production. Thus, the collective parts of STEM are greater than the individual subjects. If student teachers do not understand the connection between STEM subjects and see their overlap, they lack the overall concept of the endeavors of the STEM fields and the importance of integration.

Conversely, the engineering portion of the STEM-rich professional development integrated all areas of STEM. It was taught for 4 full days during the Summer Institute utilizing EiE curriculum from the Boston Museum of Science. In comparison to the other components of the professional development, EiE did uniquely integrate the STEM areas. For example, student teachers completed the lesson “Bridge Building” that focused on balance, force, and civil engineering. Using the engineering design process and applying science, mathematics, and technology, the student teachers learned about civil engineering while designing and building their own bridges. Because engineering naturally applies mathematics, technology, and science, the Summer Institute provided student teachers with a unique opportunity to integrate all of the STEM subjects. The Summer Institute was the one time during the professional development where student teachers got to experience the “an interdisciplinary approach to STEM instruction.”

<u>Lack of understanding of importance of STEM</u>. As a result of the lack of integration of STEM in the professional development, student teachers reported a disconnect in understanding the rationale for STEM education and its implications for the economy and society. Some student teachers reported that they did not understand the big picture regarding why and how STEM is important and connected to societal needs. One student teacher stated:

> I feel like I have a lot of pieces and I can put some of them together but I feel like I am missing the big picture, like I get all the little parts but I’m not seeing the big picture.

Another student teacher shared that she wished she learned more about “what STEM is. I feel like that was kinda just breezed over, so I feel like we all have that question of what necessarily are we trying to do? What is STEM?” Even after completing the yearlong STEM-rich professional development program, some of the student teachers did not understand the importance of fostering interest in STEM in their students or the relationship between human needs and fulfillment with scientific advancements. The rationale for teaching STEM subjects to their students was lost on most of the student teachers.

The weaknesses of the STEM-rich professional development program are all connected to the lack of integration among the STEM subjects in the STEM-rich professional development program. There was an uneven growth of confidence and skills among the STEM areas as well as a lack of knowledge about the importance of STEM. Although there were many key takeaways and learning from the student teachers during the STEM-rich professional development program, the lack of integration hindered some of the central understandings about the rationale for teaching STEM.

Strengths and Weaknesses of the Clinical, Co-Teaching Model of Student Teaching

UTEACH is a unique elementary teacher preparation program at CSULB because it includes a clinical, co-teaching model of student teaching. The UTEACH program requires student teachers to complete a full year of student teaching, compared to only one semester as required in most traditional student teaching programs. This residency, clinical model is designed so student teachers take their methods courses concurrently as they student teach, enabling the student teachers to immediately apply their learning to the classroom. The student teachers are in the classroom student teaching 4 hours 4 days a week and 1 full day per week; they take their methods courses in the afternoons of their half-days. Student teachers stay on the elementary school campus to take their methods courses as part of the residency, clinical model. Furthermore, student teachers in the UTEACH program are placed in pairs in a co-teaching model, in which they have a partner student teacher to work with and learn from in addition to their master teacher and university supervisor.

Co-teaching model of student teaching. The co-teaching model of student teaching is an extremely unusual aspect of the UTEACH program because student teachers are in pairs for their student teaching assignment. The student teacher partners are together in the classroom 4 hours per day plus 1 full day each week for a full academic year. They learn the art of teaching together, building on each other's strengths and weaknesses. They provide feedback to one another, create lesson plans together, co-teach certain lessons, support one another, and learn classroom management strategies together. The student teachers become a team, a partnership. In many cases, the student teachers also meet outside of the classroom to plan upcoming lessons and reflect on their teaching. The amount of time that the partner student teachers spend together creates a support system unique to the UTEACH co-teaching model of student teaching. This is different from the traditional model of student teaching in which one student teacher is placed in a classroom with a master teacher for a semester.

There are major benefits of a co-teaching model of student teaching, such as collaboration, immediate feedback, and comradery. However, there are drawbacks to the co-teaching model, including the potential for one partner to take advantage of the other and not contribute his/her fair share.

Advantages of a co-teaching model of student teaching. Participants reported that the co-teaching model of student teaching fostered collaboration and moral support, because both partners "were in it together," as one participant reported. Additionally, the co-teaching model enabled student teachers to learn from one another throughout their student teaching program. One participant stated:

> Having a partner, it's nice to have someone to collaborate with and to bounce ideas off of. If you are unsure about this or this, you have someone to ask, someone that can help you prepare stuff or, you know, help the kids one on one, that kind of thing.

This illustrates the participant's experiences about collaborating with her partner student teacher. Eight out of 10 of the participants shared this feeling of appreciation for the opportunity to learn together with their partner student teacher throughout their student teaching program.

A co-teaching model of student teaching allows for student teachers to use peer coaching as a way to observe one another and then provide immediate, tailored feedback. Peer coaching is a cyclical process that begins with a pre-conference to specify an area of focus for the peer coaching, then involves an observation of one partner teaching a lesson, concludes with specific feedback on areas of strength and areas that can be improved based on evidence from the observed lesson, and then repeats again with a new area of focus. Goker (2006) defines peer coaching as "non-evaluative, based on classroom observation followed by feedback, and intended to improve specific instructional techniques" (p. 240).

Half of the participants reported in their interviews that peer coaching helped them learn specific strategies for improving their teaching through the feedback given by their partner. One participant explained:

> It's nice having someone who knows what I'm going through in my classroom and someone to talk to about how or what we can do for the next day or what I can so for the lesson, as well the peer coaching that we've been doing throughout the year. She has been able to observe me teaching lessons and I've been able to observe her, so we can give each other lots feedback on that.

Peer coaching helped the student teachers improve their classroom management strategies, as well as deepen their understanding of the content they were teaching through collaboration with their partner student teacher. All of the master teachers reported that the use of peer coaching by the partner student teachers helped them learn from one another. This connects to the literature that explains that peer coaching improves instruction through collaboration (Britton & Anderson, 2010).

Student teachers were expected to use a peer coaching log to record their peer coaching observations, reflections, and recommendations once per week (Appendix F). The collected peer coaching logs exemplify the feedback given to one another regarding classroom management, content knowledge, and teaching strategies. For example, one peer coaching log from a fourth grade math lesson on comparing mixed numbers included specific feedback on the strengths of the lesson as "students were engaged, great anticipatory set" and "asked why/how higher level thinking questions [to] drive the lesson." A recommendation for this lesson was the "purpose of the lesson is to have students check answers [so] emphasize making an inference before the problem and checking on that prediction after." Another peer coaching log on a math "Problem of the Day" lesson contained detailed comments on the strengths of the lesson including "used think aloud method which helped students to understand why" and "encouraged students to 'add on' to others' explanations." The recommendations for this student teacher included "encourage more students to volunteer—the same ones were volunteering" and "use 'thumbs up/down' to check for understanding." These types of peer responses are similar to the feedback a master teacher or university supervisor would give to the student teachers.

Based on self-reported data, such as the interviews with student teachers and master teachers, and the evidence collected from the peer coaching logs, peer coaching was one way that partner student teachers supported one another and learned from each other throughout their yearlong student teaching program and a strength of the clinical, co-teaching model of student teaching.

Disadvantages of a co-teaching model of student teaching. Out of the five student teaching partnerships (8 out of the 10 participants), one was different from the others. Compared to the other student teachers' experiences in the co-teaching model of student teaching, it was reported that one of the student teacher partnerships was not beneficial, but a burden. It was a burden because one of the partners had to carry the load of both partners, did not get as much feedback as other partnerships, and did not get as much one-on-one time with the master teacher. One student teacher did not do their share of the work and instead relied on their partner to pick up the slack. This created a situation of stress for the other partner because she felt accountable for her partner. In this situation, the student teacher partnership hindered both of the student teachers' learning. If the student teachers had been in a traditional model of student teaching, this would not have happened because they would have been by themselves.

Some student teacher participants shared that having two teachers in the classroom does not replicate the reality of a real classroom, where a single teacher is responsible for everything from planning the lesson to executing the lesson all day, every day. This is a common fear according to studies by Bullough et al. (2003) and Nokes et al. (2008). With a traditional student teaching model, the student teacher candidate has the opportunity to stand alone with the support of a master teacher.

Interestingly enough, although some student teachers shared their fear that a co-teaching model of student teaching does not replicate a real in-service teaching experience, most of the student teachers reported that they learned a lot from their partner student teacher and felt that it was valuable to have a partner. Additionally, all of the master teachers reported that the co-teaching model of student teaching is beneficial because it teaches the student teachers the importance of collaboration, which is essential to teaching.

Another disadvantage of a co-teaching model of student teaching is pre-service teacher autonomy and interdependence. It was reported by a few of the participants that student teachers with a partner had more "down time" because there were three teachers total in the classroom (including the master teacher). Additionally, the pair of student teachers may rely on each other too much. One master teacher stated:

> There's always one who leans too much on the other. There's usually one who is either getting the other one to help them or they are doing the work for them. I found that it's not a true balance.

As a result, student teachers in a co-teaching model of student teaching may not be as self-sufficient as student teachers in a traditional model of student teaching. This disadvantage is found in the literature (Goodnough et al., 2009).

<u>Support is critical</u>. All of the student teachers reported that the amount of support they received in the clinical, co-teaching model of student teaching was critical to their success. Support came from their university supervisor, partner student teachers, master teachers, methods professors, and their student teaching cohort. One student teacher described the support within the clinical, co-teaching model of student teaching as

“unbelievable.” When asked how the UTEACH program helped her grow as a teacher, one student teacher answered:

> Definitely the support of my whole cohort. We all have the same method courses so just being in the classroom together in the afternoons, being on the school campus in the mornings together. Our professors are also in the PD or attend the PD night so they know what’s going on. They could talk to us in relation to [the PDs]. And then the support of our supervisor, who also attends and we’re all on the same page, so it’s not like “I have to fill you in on this. I have to fill you in on that.” And it’s just one big happy family.

This student teacher highlighted various components of the clinical, co-teaching model of student teaching that is conducive to high levels of support, including the residency model of taking methods courses together on the elementary campus and the cohort model.

Eight out of 10 student teachers reported that their partner was a huge support for them. The co-teaching model of the UTEACH program fostered collaboration and encouragement. The use of peer coaching provided student teachers with a protocol to give feedback, provide recommendations, and praise one another. The co-teaching model also encouraged student teachers to plan lessons together and reflect on the delivery of the lessons throughout the yearlong student teaching program.

Ultimately, the layers of support that permeated the clinical, co-teaching model of student teaching boosted student teachers’ confidence, as reported in interviews, peer coaching forms, and journal entries. Student teachers’ confidence increased because the support given focused on lesson design, content knowledge, pedagogical strategies, classroom management, and lesson delivery.

<u>Growth and maturation of student teachers</u>. When looking at the data over time, the growth and maturation of the student teachers is apparent. Although this was not

directly coded for in the data analysis process; however, the theme emerged when analyzing the data over time. Because the UTEACH program is a yearlong, clinical, co-teaching model of student teaching, student teachers develop and become increasingly more knowledgeable about various aspects of teaching, including pedagogical strategies and effective instruction, throughout the program. Student teachers' lesson plans, reflections of videotaped lessons, journal entries, and peer coaching forms demonstrate the student teachers' growth and maturation throughout their student teaching program.

One example of the maturation of the student teachers is the sophisticated use of vocabulary in their reflections of their videotaped lesson from fall to spring. In fall, one student teacher reflected about the beginning of her lesson and the engagement of her students and wrote: "The engagement was good with the book. The students were actively engaged by sitting quietly and following along." This same student teacher focused again on the beginning of her lesson and the engagement of her students in her reflection on her spring videotaped lesson by writing: "The introduction to the lesson connected the students' prior knowledge of volume from the past lessons so the students were engaged and participated well." The second reflection exemplifies the student teacher's growth and maturation over time in understanding key instructional strategies.

Similarly, the feedback given during the peer coaching process developed over time in terms of sophistication and specificity. Figure 9 represents the feedback given from a student teacher to her partner in spring during peer coaching.

Strengths:
-Referred to previous lessons and had students look back at their notes—built on schema.
-Great interaction with students!
-Doing problem step-by-step and checking boards each time keeps them on task and engaged.
-TPR—all students answered on their fingers.
-Great! Drawing number line to concretize abstract thinking.
-Restated Ren's reasoning so others could hear in a different way.
-All students on task—no behavior issues at all!

Recommendations:
-Students were a little confused about what the estimate should be, try drawing a picture with a simpler problem.
-Have students explain why an estimate is incorrect.
-Try a non-example that is clearly wrong so students see what not to do.
-Make sure to always check the estimate—objective

FIGURE 9. Feedback given on a peer coaching form in the spring.

The feedback given in this peer coaching form is an example of a sophisticated use of vocabulary and illustrates a high level of understanding of best teaching practices by the student teacher giving the feedback.

Student teachers' confidence and content knowledge in all subjects, including STEM, progressed over time. One master teacher explained:

> I think [the student teachers] are well prepared. . . . I think that the fact that this whole UTEACH program teaches two semesters as opposed to one. I think it allows for a lot more growth and a lot more chances to apply what they have been learning.

Applying their learning from their methods courses, prior experiences in student teaching, and the STEM professional development impacted the knowledge and expertise of the student teachers. As explained by the master teacher, the yearlong student teaching program enabled the student teachers to become more seasoned in their confidence, content knowledge, and teaching practices. Additionally, the student teachers' use of vocabulary became more sophisticated over time and their understanding of teaching expanded throughout the yearlong student teaching program.

Impact of Common Core State Standards on the STEM-Rich Professional Development

This case study was conducted during the 2013–2014 school year, and this happened to be the 1st year the state of California implemented CCSS for language arts and mathematics. CCSS is a nation-wide reform in education, focusing on critical thinking skills, transferability of knowledge, and preparing students to be college and career ready. Instead of focusing on learning basic facts and skills in preparation for the standardized test under No Child Left Behind, CCSS in mathematics (CCSS-M) requires shifts in the curriculum and instructional strategies, incorporating focus, coherence, and rigor in mathematics. Focus includes the "greater focus on fewer topics," while coherence refers to the purposeful "linking of topics and thinking across grades," and rigor "pursues conceptual understanding, procedural skills and fluency, and application with equal intensity" (Common Core State Standards Initiative, 2015a, para 3). For example, California's previous mathematics standards included 60 standards in third grade, while CCSS-M has only 25 third grade standards; thus, there are fewer topics at each grade level providing more focus and allowing teachers to teach at a deeper level. The National Council of Teachers of Mathematics (NCTM) offers their support of the standards by stating "the Common Core State Standards offer a foundation for the development of more rigorous, focused, and coherent mathematics curricula, instruction, and assessments that promote conceptual understanding and reasoning as well as skill fluency" (2013, para 1). Additionally, CCSS-M includes Standards for Mathematical

Practice as well as grade level specific content standards. These eight Standards for Mathematical Practice describe important “processes and proficiencies” of mathematical thinking, including “problem solving, reasoning and proof, communication, representation, and connections” (Common Core State Standards Initiative, 2015b, para 1). The Standards for Mathematical Practice are K–12 standards; thus, the same eight mathematical thinking processes are taught and developed from Kindergarten to 12th grade so students are continually learning critical thinking, problem solving, and how to communicate their reasoning, becoming more sophisticated the older they get.

Because the CCSS are radically different from the former California standards, implementing the standards has been challenging for teachers. In the school district where this study took place, teachers were expected to teach the new CCSS-M standards utilizing district created resources, including unit guides and unit assessments, without the support of a textbook. Because of the drastic changes and lack of resources, many of the master teachers expressed during their interviews that the curriculum was “fragmented” and that they were learning the new standards as they went, which challenged many aspects of being a master teacher, such as long-term planning, modeling effective teaching strategies, and the lack of feeling like an expert of the content taught in their grade level. Additionally, the accountability process raised a lot of questions from master teachers regarding CCSS. Because the end-of-year summative test was changing to a computer adaptive test as well as a performance task, the ambiguity and unknowns surrounding it added to the master teachers’ stress throughout the school year.

As a result, this was a year of dramatic change for all of the participants. CCSS is a massive educational reform, and its implementation impeded the master teachers’ time, resources, focus, and effort in their learning of STEM. The critical question that must be asked is did the CCSS reform overshadow the focus on STEM?

Master teachers found a dissonance between CCSS and STEM, while student teachers found a convergence. All of the master teachers reported that their focus was primarily on CCSS, not STEM, throughout the school year. Even though the master teachers attended the yearlong STEM professional development along with the student teachers, the new curriculum introduced as a result of CCSS required their full attention and focus as they learned the new standards. One master teacher shared her feelings about the new CCSS curriculum:

> Actually, all of the subjects kind of feel a little bit fragmented right now, and even with math, I know I have heard a lot of teachers saying that, we just don't feel like we have the sequence down of what order to teach it in. I think the district is still trying to figure that out too, so it's very fragmented. Like one day we are working on this, well, now we have to work on this that is not related to this. It doesn't feel like it flows yet. I think as all of that comes together, it's going to be good.

The emphasis on a fragmented curriculum was reported by all of the master teachers. CCSS shifted the attention of the master teachers from STEM to learning the new standards. This shift may explain why master and student teachers focused on mathematics more than science, engineering, or technology. Triangulation of data revealed an emphasis on mathematics due to the changes in standards, including data from the interviews with student teachers. Many of the student teachers shared that they did not teach a lot of science, but spent more time on mathematics. One student teacher explained, "We didn't do a lot of science in the beginning, I think because of the new curriculum. It's all been kind of thrown out, so they've tried to focus more on the reading and math and that stuff." Consequently, master teachers found a dissonance between CCSS and STEM because CCSS overshadowed their learning from the STEM professional development. It was a sink or swim year for the master teachers, and unfortunately, CCSS won out over STEM.

Contrarily, student teachers found a convergence between CCSS and STEM. One student teacher stated in her interview, “Common Core is STEM to an extent.” Student teachers recognized and acknowledged the overlap between CCSS and STEM. For example, when referring to CCSS, many of the student teachers related their learning about STEM to the instructional shifts required by the CCSS and the Standards for Mathematical Practice. Student teachers described the focus on building students’ conceptual understanding as a key component of both CCSS and STEM. Furthermore, asking students higher-level questions, engaging students through inquiry, focusing on critical thinking (not simply memorizing procedures) are all elements of CCSS and STEM. One student teacher wrote in her journal: “Usually Common Core and STEM really involves the students with their own learning. In my lessons, I have encouraged group discussion and peer tutoring so they learn from each other and learning in many ways.” Furthermore, most of the student teachers expressed in their interviews that integrating content is essential to both CCSS and STEM.

Although all of the student teachers also had to learn to implement CCSS along with their master teachers during their student teaching program, most of the student teachers were able to articulate the common characteristics of CCSS and STEM. Some of those common characteristics include implementing inquiry-based lessons, focusing on conceptual understanding, building upon critical thinking and problem solving, as well as integrating content. The thinking processes and engagement involved in STEM lessons corresponds with CCSS and the Standards for Mathematical Practice. One student teacher explained in her interview that she felt prepared for entering the teaching profession and would be able to implement CCSS and STEM:

> I feel more comfortable teaching science and math, especially with those PD classes. And knowing that, even though now Common Core math, there aren't really textbook support or worksheet support, but there things that we can do with our students that relate to STEM, that relate to inquiry-based learning that I could practice with the students and not really have a panic or be panicked about teaching Common Core math.

This student teacher was able to relate the importance of inquiry-based learning to both CCSS and STEM.

It is interesting that student teachers found a convergence between CCSS and STEM, while their master teachers found a dissonance. There are many potential explanations for this finding. One explanation is that the stakes are not as high for student teachers compared to master teachers in implementing and preparing students for CCSS. Another reason may be that student teachers are building their foundation of understanding about teaching and learning. Because student teachers are in the process of learning about teaching, they did not have to unlearn previous standards and instructional practices to feel prepared to teach CCSS as their master teachers did. Whatever the reason for the difference in views about CCSS and STEM, this is an area of future research. In this study, the data reveal that student teachers found connections between CCSS and STEM and were able to apply their learning from the STEM professional development sessions when teaching mathematics and science.

Conclusion

In order to explore how the STEM-rich, clinical, co-teaching model of student teaching prepared future elementary teachers and how the implementation of CCSS impacted it, a yearlong case study was conducted including both qualitative and quantitative data. The data sources collected include interviews with student and master teachers, lesson plans, reflections on lesson plans, journal entries, videotaped lessons, and pre- and post-surveys. Open coding data analysis was utilized to analyze the qualitative data sources, while a paired-samples *t*-test was used to analyze the quantitative pre- and post-survey data.

"How did the STEM-rich, clinical, co-teaching model of student teaching prepare student teachers to effectively teach STEM content?"

In answering this research question, several themes emerged when triangulating the various data sources. The strengths of the STEM-rich professional development that helped prepare the student teachers to effectively teach STEM content include building theoretical understandings of teaching STEM subjects, connecting and applying the theory learned in the STEM-rich professional development to practice, and increasing student teachers' confidence in teaching science and mathematics. Moreover, the co-teaching, clinical model of student teaching fostered collaboration and moral support among the student teachers. Additional strengths include the ample amount of support provided to the student teachers and the growth and maturation of student teachers throughout the yearlong student teaching program.

Although many strengths of the STEM-rich clinical co-teaching model of student teaching surfaced, several limitations emerged as well. The growth of confidence in teaching STEM content and the knowledge of the theoretical foundations of STEM instruction were uneven among the STEM areas; engineering and technology were areas of weakness. Additionally, the lack of integration of the STEM areas in the professional development impeded the student teachers' application of STEM, while contributing to the lack of understanding about the importance of STEM and its implication for students and society. Furthermore, the co-teaching model was criticized by some participants for its disconnect to the reality of teaching.

"How did the implementation of the educational reform effort for the Common Core State Standards impact the STEM-rich, clinical, co-teaching model of student teaching?"

Because this study occurred during the 1st year of CCSS implementation, the reform impacted the findings of this study. Master teachers found a dissonance between CCSS and STEM, while student teachers found a convergence. Student teachers recognized and acknowledged the overlap between the characteristics of CCSS and STEM, including focusing on critical thinking, problem solving, and inquiry-based teaching.

Next, Chapter 5 will provide a discussion of the findings of this study by connecting them to the literature and utilizing the strengths and weaknesses of the STEM-rich, clinical, co-teaching model of student teaching to describe an ideal model of a STEM-rich professional development program for elementary teachers. Implications for future practice, policy, and research will also be discussed. Finally, the significance of this study will be revisited to determine its place within the literature and its implications for STEM educational reform.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS, IMPLICATIONS, RECOMMENDATIONS FOR POLICY AND PRACTICE, AND SUGGESTIONS FOR FURTHER STUDY

A case study involving the collection of various types of qualitative and quantitative data sources was conducted to explore how a STEM-rich, clinical, co-teaching model of student teaching prepared future elementary teachers to effectively teach STEM content. Student teachers who participated in this study were a part of the Raising the Bar for STEM Education in California program, which provided them with professional development focused on STEM in addition to their yearlong, residency student teaching program. A second objective of this study was to examine how the implementation of CCSS impacted the Raising the Bar for STEM Education in California program.

The research questions that guided this study were:

1. How did the STEM-rich, clinical, co-teaching model of student teaching prepare student teachers to effectively teach STEM content?

2. How did the implementation of the educational reform effort for the Common Core State Standards impact the STEM-rich, clinical, co-teaching model of student teaching?

Ten student teachers, five master teachers, and one university supervisor were participants in this case study. Numerous data sources were collected, including qualitative interviews, observations through videotaped lessons, lesson plans with reflections, student work, peer coaching forms, journal reflection, and quantitative pre- and post-surveys. Multiple cycles of open coding were performed until themes emerged that answered the research questions. A paired samples *t*-test was conducted to measure the difference in student teachers' self-efficacy in teaching science and mathematics from the beginning of the professional development to its end.

The final chapter of this study will be presented in three sections. First, the key findings will be summarized. Second, based on the findings of the study, implications and recommendations for STEM professional development will be presented. Third, further recommendations for policy, practice, and research will be shared.

Summary of Findings

In answering the research questions guiding this study, four major themes emerged: strengths of the STEM-rich professional development; weaknesses of the STEM-rich professional development; strengths and weaknesses of the clinical, co-teaching model of student teaching; and the impact of CCSS on the STEM-rich professional development program.

"How did the STEM-rich, clinical, co-teaching model of student teaching prepare student teachers to effectively teach STEM content?"

The STEM-rich, clinical, co-teaching model of student teaching had two major components: the STEM-rich professional development program and the clinical, co-teaching model of student teaching. Although each component was intertwined throughout the Raising the Bar for STEM Education in California program, the findings have been separated in order to draw conclusions about each separately and to answer the research questions.

STEM-rich professional development program. The data showed that the student teachers developed a strong understanding of the theoretical underpinnings of STEM. All of the student teachers explained that STEM content should be taught through the use of inquiry-based, hands-on, investigative, and student-centered lessons. The professional development sessions modeled the use of inquiry and problem solving through active learning, which helped the student teachers expand their own understanding of the pedagogical strategies necessary for teaching STEM content. Time to collaborate with master teachers and other student teachers was embedded into the STEM-rich professional development sessions, which increased the student teachers' understanding of the instructional practices for teaching STEM subjects.

Student teachers applied their learning from the STEM-rich professional development to the classroom by replicating some of the activities with their students. The 5E lesson plan for teaching science through inquiry was a major takeaway from the professional development. In mathematics, student teachers learned the importance of developing their students' conceptual understanding by asking students to reason with mathematics, using manipulatives and visuals, and using multiple representations. Additionally, activities from the STEM-rich professional development were applied by the student teachers during STEM Family Night.

Another key finding about the STEM-rich professional development program was that it helped increase student teachers' confidence in teaching science and mathematics.

A majority of the student teachers had a growth mindset regarding their own learning about STEM. Most of the student teachers shared their excitement for teaching STEM content in the future when they have their own elementary classrooms based on their experiences in the STEM-rich professional development program. The data collected in this study leads to the conclusion that student teachers are willing and likely to teach STEM content to their students in their future classrooms.

Although the student teachers increased their confidence and knowledge of STEM through the STEM-rich professional development, the growth was uneven among the four STEM content areas. Student teachers reported that they felt more prepared to teach science and mathematics than technology or engineering. Most of the student teachers did not try to teach technology or engineering while they were student teaching, and all stated that they needed more professional development in those areas in the future. Additionally, the lack of integration of the STEM areas during the professional development hindered the student teachers' application of STEM and their understanding of "an interdisciplinary approach to STEM instruction." None of the student teachers tried teaching an integrated STEM lesson to their students. In fact, most of the student teachers did not understand how STEM content is intertwined and could be taught using an integrated approach. The STEM-rich professional development did not model integrating STEM content, but rather focused on each area of STEM separately. Moreover, some student teachers misunderstood the overall rationale of STEM and its implication for the economy and society.

Clinical, co-teaching model of student teaching. The clinical, co-teaching model of student teaching is different than a traditional student teaching program in that two student teachers are placed together in a classroom with a master teacher, forming a partnership. The student teachers complete a yearlong student teaching program, spending one semester in a primary grade classroom and one semester in an intermediate grade classroom. Additionally, the student teachers take their methods courses on site at the elementary school where they student teach with a cohort of other student teachers at the same site, creating a residency, clinical model of student teaching.

The co-teaching model had many benefits. Student teachers collaborated with their partner and learned teaching strategies together, building on each other's strengths and learning from each other's weaknesses. The partners provided feedback to one another, created lesson plans together, supported one another, and provided moral support throughout their student teaching experience. Peer coaching was a specific strategy that helped the student teachers improve their practice.

It was also found that the clinical, co-teaching model of student teaching promoted the growth and maturation of the student teachers. Student teaching for 1 complete academic school year, instead of only one semester, helped the student teachers become more knowledgeable about various aspects of teaching, including pedagogical strategies and effective instruction. The student teachers' use of vocabulary and description of their own and their partners' teaching became more sophisticated over time.

However, two disadvantages were found in the data. At times, a partner student teacher could hinder the other partner's learning. It was reported that one student teaching partnership was unequal in that one student teacher did not do their share of the work and took advantage of their partner. Autonomy and interdependence were drawbacks of co-teaching. Another disadvantage regarding the co-teaching model was that some student teachers felt that it did not replicate the reality of a real classroom in which there is only one teacher.

"How did the implementation of the Common Core State Standards impact the STEM-rich, clinical, co-teaching model of student teaching?"

This case study was conducted during the 2013–2014 school year. Coincidently, this was the 1st year of implementation of CCSS in California. Because CCSS is radically different than California's previous standards, teachers had to learn new teaching strategies and develop their content knowledge in order to teach the new standards. Therefore, implementing CCSS was challenging for teachers of all levels of experience. It was as if all teachers were 1st-year teachers again.

The implementation of CCSS greatly impacted the STEM-rich professional development because master teachers were more focused on CCSS than on STEM. All master teachers reported that they disregarded STEM in an effort to concentrate on implementing CCSS. Master teachers viewed the two reforms, CCSS and STEM, as competing issues and CCSS won out over STEM largely because of the pilot assessment that took place in spring 2014.

In contrast with the master teachers' experiences, student teachers that participated in the Raising the Bar for STEM Education in California program did not view CCSS and STEM as rival reforms. Instead, student teachers found a convergence between CCSS and STEM because they found commonalities between them. Some of those common characteristics included implementing inquiry-based lessons, focusing on conceptual understanding, building upon critical thinking and problem solving, as well as integrating content.

The key findings of this study connect to the conceptual framework and align with other literature. However, this study provides a unique lens into preparing future elementary teachers to effectively teach STEM content that is not found in the literature.

Implications and Recommendations for STEM Professional Development

The findings of this research study provide insight for future STEM professional development by school districts. Current research on professional development lacks empirical research on STEM-specific professional development programs. Because elementary teachers lack the content knowledge and confidence to effectively teach STEM subjects (DeJarnette, 2012; Duncan et al., 2011; Hill et al., 2005), STEM-focused professional development is a critical need for elementary teachers. Even though teacher preparation programs should also emphasize STEM content, elementary teachers will need additional professional development once they become in-service teachers to continue to build their PCK in STEM subjects. As such, based on the strengths and weaknesses of the Raising the Bar for STEM Education in California program, essential elements of effective STEM professional development will be described that incorporates the best features of this program, with additional features that have been derived from the conceptual framework in Chapter 1 and the research literature in Chapter 2 (Appendix K).

Conceptual Framework

The conceptual framework that guided this study intertwined PCK with adult learning theory. The theory of PCK states that teachers need a deep understanding of both content and pedagogy in order to effectively teach a subject to students (Shulman, 1986). These habits of mind are essential for teachers. Examples of PCK include knowledge of instructional strategies, students' needs, assessment, curriculum, and the content knowledge of the subject (Eilks & Markic, 2011; Shulman, 1986).

Adult learning theory describes qualities necessary for adults to learn (Knowles, 1980). Self-concept, experience, readiness to learn, orientation to learning, and motivation to learn are characteristics of adult learning theory (Miroballi, 2010). Adult learners "must have purpose in what they are learning. Learners must understand how this learning experience will help them solve a problem or complete a future task" (Gomez, 2012, p. 42). Adult learning theory explains that adults learn best when they are involved in their learning and when the new learning is connected to their experiences (Gomez, 2012; Knowles, 1980). Figure 10 is a model of the conceptual framework utilized in this study blending adult learning theory with PCK.

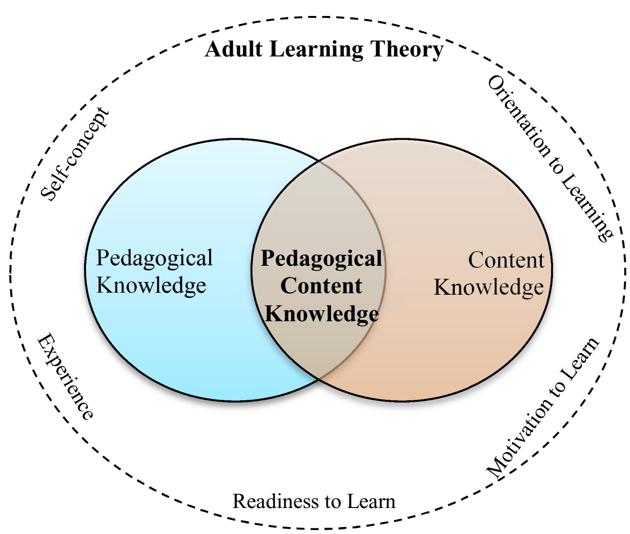

FIGURE 10. Conceptual framework intertwining PCK and adult learning theory.

Essential Elements of Effective STEM Professional Development

Based on the findings of this study, the conceptual framework, and key literature, essential elements of effective STEM professional development include clear goals, a design that provides ongoing sessions, and components that are targeted to meet the needs of the teachers in the professional development program in order to build teachers understanding of "an interdisciplinary approach to STEM instruction." Table 6 shows the essential elements of effective STEM professional development.

TABLE 6. Essential Elements of Effective STEM Professional Development

Features	Description
Goals	− Improve elementary teachers' pedagogical content knowledge and confidence in teaching STEM subjects − Increase the amount of time spent teaching STEM subjects in elementary classrooms
Design	− Yearlong professional development program
Components	− Emphasize the importance of STEM fields to the economy and society as the rationale for teaching STEM subjects in elementary classrooms − Build pedagogical content knowledge through focusing on both content and pedagogical strategies − Integrate STEM subjects through focusing on engineering − Explicitly link STEM to Common Core State Standards and Next Generation Science Standards through pedagogical teaching strategies and practices − Develop the foundation of STEM professional development around the characteristics of Adult Learning Theory − Foster reflective, collaborative communities of practice

Goals of STEM professional development. The goal of STEM professional development should be twofold: To improve elementary teachers' PCK and confidence in teaching STEM subjects and to increase the amount of time spent in elementary classrooms on teaching STEM content. In order to meet these goals, STEM professional development should provide targeted, ongoing professional development in STEM content to elementary teachers.

Design of STEM professional development. STEM professional development should span an entire academic school year. Research reveals that in-depth professional development that is ongoing can lead to authentic change in teachers' PCK, confidence, and practice (Darling-Hammond & McLaughlin, 1995; Eilks & Markic, 2011; Garet et al., 2001). Professional development in STEM that occurs throughout the year can foster a growth mindset that will improve teachers' confidence in teaching STEM subjects (Dweck, 2006), as the findings of this study revealed.

Components of STEM professional development. STEM professional development should emphasize the importance of STEM fields to the economy and society as the rationale for teaching STEM subjects in elementary classrooms; build PCK through focusing on both content and pedagogical strategies; integrate STEM subjects through focusing on engineering; explicitly link STEM to CCSS and NGSS through pedagogical teaching strategies and practices; develop the foundation of STEM professional development around the characteristics of adult learning theory; and foster reflective, collaborative communities of practice.

Emphasize the importance of STEM fields to the economy and society as the rationale for teaching STEM subjects in elementary classrooms. Based on the finding of this study that student teachers did not understand the rationale for STEM and its importance to society, it is recommended that STEM professional development begin by explaining why STEM is critical for the economy and society and its implications for education at all levels, including elementary education. Participating elementary teachers need to have the big picture as to why it is essential to teach STEM subjects to their students before diving into the core curriculum of the professional development. This gives teachers a purpose for learning about STEM fields. Thus, starting STEM professional development with "Why STEM?" will help all elementary teachers to understand why they are participating in the program. For example, to provide teachers with background information about the importance of STEM, participants in the professional development should learn about the projected increase in STEM careers compared to other careers and the small number of STEM graduates in America compared to other countries (Craig et al., 2012). Understanding the implications of STEM on the economy and society is an essential element of effective STEM professional development.

Build pedagogical content knowledge through focusing on both content and pedagogical strategies. In order to be effective, it is recommended that STEM professional development for elementary teachers focus on both STEM pedagogy and content in order to build teachers' PCK in STEM subjects (Shulman, 1986). Based on the positive and negative findings of this study and the theory of PCK, elementary teachers need to both develop their understanding of STEM content and learn how to effectively teach STEM content to their students. Professional development that focuses on only content knowledge or only pedagogical knowledge is not sufficient in impacting teachers' PCK or their practice (Eilks & Markic, 2011; Van Driel et al., 2001). Therefore, effective STEM professional development should include both STEM content knowledge and pedagogical knowledge for teachers in order to impact their PCK in STEM subjects.

Integrate STEM subjects through focusing on engineering. Focusing on the integration of STEM is an essential element of effective STEM professional development in order to develop "an interdisciplinary approach to STEM instruction." Rather than spending time separately learning about science, technology, engineering, and mathematics, it is recommended that STEM professional development concentrate solely on the integration of STEM using an engineering-focused approach. Engineering is applied science, technology, and mathematics. Thus, a focus on engineering fosters integration of STEM in elementary classrooms and it makes good use of the little time available to elementary teachers to teach these subjects.

STEM professional development could use curriculum created by the Boston Museum of Science called Engineering is Elementary (EiE). The mission of EiE is to "support educators and children with curricula and professional development that develop engineering literacy" (EiE, 2014a, para 1). The EiE curriculum consists of engineering units that correspond with science topics for first through fifth grades. It integrates STEM subjects but also connects to literacy in that each unit includes a storybook that "introduces basic engineering content and related science topics and highlights engineering activities that children will do in the unit. Each story focuses on a child character from a different racial or ethnic background or country and includes original illustrations" (EiE, 2014b, p. 2). The EiE unit then continues by including lessons that take students through the engineering design cycle to design a solution to the problem for each unit. In the EiE units, students apply science, technology, and mathematics concepts during the engineering design cycle as they test and retest their prototypes (EiE, 2014a). Because elementary teachers primarily focus on language arts and mathematics, integration of STEM subjects along with reading and writing is the way to bring STEM to elementary classrooms.

Explicitly link STEM to Common Core State Standards and Next Generation Science Standards through pedagogical teaching strategies and practices. Furthermore, effective STEM professional development should focus on the connection between STEM, CCSS, and NGSS. Effective professional development needs to "be connected to other aspects of school change" (Darling-Hammond & McLaughlin, 1995, p. 598). As such, it is recommended that STEM professional development explicitly emphasize the convergence between the multiple reform efforts so teachers understand how STEM, CCSS, and NGSS mutually benefit one another through pedagogy and practices. CCSS contains the Standards for Mathematical Practice, while NGSS includes Science and Engineering Practices. These practices include "processes and proficiencies" of mathematical and scientific thinking (Common Core State Standards Initiative, 2015, para 1). STEM professional development should foster these practices by including sessions on inquiry-based lessons, using exploration to promote critical thinking, building conceptual understanding instead of memorizing procedures, asking higher-level questions to encourage problem solving, and using the 5E lesson plan format to design engaging, hands-on, investigative lessons. Focusing on these pedagogical strategies and infusing the practices into teachers' lesson plans will assist in teaching STEM, CCSS, and NGSS. Therefore, teachers should not view teaching STEM content as one more thing to do in their classrooms, but as a tool in their toolkit to implement CCSS and NGSS.

Develop the foundation of STEM professional development around the characteristics of adult learning theory. Additionally, elements of adult learning theory, which are self-concept, readiness to learn, orientation of learning, experiences, and motivation, should be infused into the features of effective STEM professional development. It is recommended that STEM professional development be designed around the experiences of the participating elementary teachers and connected to their motivation (Knowles, 1980; Miroballi, 2010). In order to make STEM professional development immediately applicable for teachers, its activities should be separated into grade level strands. For example, Kindergarten, first, and second grade teachers should be grouped together when learning about specific activities and lessons that can be replicated in their classrooms, as should third, fourth, and fifth grade teachers.

Additionally, STEM professional development should be inclusive of participating teachers' self-concept as it is connected to confidence and mindset. An example of this is surveying participating teachers before the STEM professional development begins to learn about their perceptions of their self-concept and using this information to tailor the professional development sessions to build upon teachers' strengths and motivation. Thus, STEM professional development should utilize elements of adult learning theory to be effective.

Foster reflective, collaborative communities of practice. Based on the positive findings of this study and other key literature, it is recommended that STEM professional development build reflective, collaborative communities of practice. Darling-Hammond and McLaughlin (1995) found that engaging teachers in reflection activities, promoting communities of practice, and encouraging collaboration are elements of effective professional development. These essential elements of effective STEM professional development use Darling-Hammond and McLaughlin's research as a foundation in conjunction with this study's positive findings.

In sum, several of the described essential elements of effective STEM professional development should be implemented for any professional development, not only STEM professional development. Focusing on both content and pedagogy to increase teachers' PCK is critical for any professional development to impact teacher practice (Ball et al., 2008; Eilks & Markic, 2011). Professional development should also align to adult learning theory in that it develops teachers' self-concept, links to teachers' experiences, and is immediately applicable (Knowles, 1980; Miroballi, 2010). Additionally, professional development needs to be purposeful, targeted, and ongoing (Darling-Hammond & McLaughlin, 1995; Eilks & Markic, 2011) while developing teachers' growth mindset (Dweck, 2006). Professional development should also build reflective, collaborative communities of practice for teachers (Darling-Hammond & McLaughlin, 1995).

However, certain aspects of the essential elements of effective STEM professional development are unique to STEM in that they help teachers effectively teach STEM subjects to their students. Explaining the importance of STEM education and its implications for the economy and society during STEM professional development is crucial for teacher buy-in and for a greater understanding of STEM fields. STEM professional development should connect STEM to CCSS and NGSS and focus on integrating STEM through engineering. Therefore, utilizing all of these essential elements of effective STEM professional development can impact future professional development programs for elementary teachers.

Because there is a gap in the research regarding STEM professional development, not professional development on science or technology or engineering or mathematics but on professional development on STEM as a whole, these essential elements of effective STEM professional development should be used by school districts when implementing STEM professional development for elementary teachers. These essential elements of effective STEM professional development are significant in that they contribute to the research and impact practice across elementary education. The goal of these essential elements of effective STEM professional development is to help school districts plan professional development to impact teachers' PCK and practice in STEM subjects, which may lead to rectifying the current STEM crisis in America.

Further Recommendations

In addition to the recommendations for essential elements of effective STEM professional development, further recommendations for policy, practice, and research will be described based on the findings of this study.

Policy

Based on the findings and implications of this study, several recommendations for policy will be proposed in order to rectify the problem of elementary teachers lacking content knowledge, pedagogical knowledge, and confidence to effectively teach STEM subjects to their students.

Common vision to support California's mission of education. First and foremost, policy makers at the state level need to create a common vision for education in California that aligns CCSS, NGSS, and STEM to support California's mission to "provide a world-class education for all students, from early childhood to adulthood. . . . Together, as a team, we prepare students to live, work, and thrive in a highly connected world" (California Department of Education, 2014, para. 1). As the findings of this study illustrate, there are competing demands on teachers and without clear direction on how the multiple reforms support one another, teachers may only focus on CCSS, as the master teachers did in this study.

The alignment between California's mission statement and the expectations and requirements of CCSS, NGSS, and STEM needs to be created to clearly articulate as a common vision how teachers can "use inquiry-based instructional approaches to teach students how to reason, design experiments, analyze evidence, and justify solutions" (Read, 2013, p. 2) in order to work towards the mission of education in California (California Department of Education, 2014). This common vision should acknowledge the multiple reforms currently occurring in education, including CCSS, NGSS, and STEM, and help educators understand how are the reforms are harmonious and benefit one another. Policy makers should describe the roles of all stakeholders in education, such as higher education institutions, school districts, and philanthropy, in meeting the common vision for education in California and, in turn, striving towards the mission of education in California. Without a unified vision of STEM, education in California will continue to be fragmented.

Adoption of a yearlong, clinical, co-teaching model of student teaching by all teacher preparation programs. Based on the positive findings of this study, policy should be created that requires that all elementary teacher preparation programs at higher education institutions to adopt a yearlong, clinical, co-teaching model of student teaching. Student teaching for an entire year instead of only one semester benefits the future elementary teachers in that they have opportunities to grow and mature as pre-service teachers while trying new teaching strategies and building PCK. Research shows "extended clinical experiences of at least thirty weeks" prepares pre-service teachers significantly more than their peers in shorter student teaching programs (Darling-Hammond et al., 2005, p. 406).

The findings of this study align to other research that clinical student teaching programs better prepare future elementary teachers in comparison to traditional models of student teaching (Darling-Hammond, 2006). The benefits of a clinical model of student teaching include enabling pre-service teachers to immediately apply their learning about pedagogical theory learned in their methods courses to practice during student teaching. This allows pre-service teachers to "conceptualize teaching and enact their ideas in practice" (Darling-Hammond, 2006, p. 44). Compared to traditional student teaching, a clinical model combines theoretical and practical study in the development of elementary teachers, which better prepares them overall.

Additionally, the findings of this study support other research in determining that co-teaching models of student teaching enable student teachers to learn through collaboration, which leads to improved instructional strategies and an increase in student achievement (Bullough et al., 2003; Nokes et al., 2008). However, it is recommended that student teachers co-teach the first semester only and student teach the second semester individually, so student teachers will have the opportunity to experience teaching similar to the reality of the profession, yet still experience the benefits of co-teaching. This will alleviate the limitations of co-teaching described in the literature and in the findings of this study in which student teachers fear they did not get experience teaching on their own, while encompassing the benefits associated with co-teaching, such as increasing collaboration and the willingness to try a variety of instructional strategies in order to improve teaching and increase in student achievement (Bullough et al., 2003; Nokes et al., 2008). During the second semester, they could still do peer coaching with their former student teaching partner to continue learning from one another.

<u>Modifying multiple subject credentialing requirements to include STEM</u>. Furthermore, a policy should be created to address the lack of elementary teachers' STEM content knowledge and confidence (DeJarnette, 2012; Duncan et al., 2011; Hill et al., 2005). Based on the findings of this study and other literature, elementary teachers lack content knowledge and confidence to effectively teach STEM content. If teacher preparation programs included more STEM in their coursework, pre-service teachers could develop a deeper understanding of STEM subjects. One way to require this is to modify California Teacher Credential's (CTC) requirements for earning a multiple subject teaching credential in California by adding additional requirements that are specific to STEM. These requirements should include:

1. A comprehensive course in STEM integration that includes STEM content knowledge and pedagogical strategies in integrating STEM across the curriculum.

2. Pass an exam on STEM content knowledge.

In order to implement the proposed change in policy, teacher preparation programs at colleges and universities across California would need to create and add a STEM integration course to their program. CTC would also need to create a STEM content exam to measure teacher candidates' STEM content knowledge. Adding these additional requirements of completing a STEM integration course and passing a STEM content knowledge exam would ensure that elementary teachers are highly qualified to teach STEM content, which is a missing component in the current multiple subject teaching credential requirements.

Practice

Based on the findings and implications of this study, several recommendations for practice will be proposed for higher education institutions and for school districts. The objective of these recommendations for practice is to provide elementary teachers with the content knowledge, pedagogical knowledge, and confidence necessary to effectively teach STEM subjects to their students.

Higher education institutions. Higher education institutions need to revamp their teacher preparation programs in order to prepare elementary teacher candidates with the PCK to integrate STEM with CCSS and NGSS.

Infuse STEM in teacher preparation programs. Based on the findings of this study and other literature, it is clear that STEM needs to be infused in elementary teacher preparation programs within the methods courses and student teaching. Professors who teach methods courses should be expected to collaborate with one another to incorporate STEM into their curriculum in order to teach teacher candidates about the importance of STEM and to model how to integrate STEM with CCSS and NGSS. In student teaching, university supervisors should require pre-service teachers to practice teaching lessons that incorporate aspects of STEM, CCSS, and NGSS and that integrate STEM subjects. This would require methods courses professors and university supervisors to be trained in “an interdisciplinary approach to STEM instruction” so they can support their pre-service teachers.

Therefore, during student teaching all pre-service teachers should continue to learn about STEM subjects and the integration of STEM subjects. The proposed model of professional development should be included in all pre-service teachers’ student teaching programs. Teacher preparation programs will need to coordinate the professional development at the elementary school site so student teachers get an in-depth understanding and a variety of experiences in STEM during student teaching that will prepare them to effectively teach STEM content to their future students.

Additionally, all courses in elementary teacher preparation programs, including methods courses and student teaching, should emphasize content and pedagogy, thereby building teacher candidates’ PCK. Typically, teacher preparation programs focus on primarily pedagogy; however, future elementary teachers need to learn more about both content and pedagogy in their pre-service program in order to improve their PCK in all subjects, but specifically in STEM areas (Epstein & Miller, 2011; Weiss et al., 2001). Adding STEM content knowledge as well as pedagogical knowledge in teacher preparation programs may help elementary teachers effectively teach STEM subjects to their students, aiding in building the foundation for STEM content areas that will help students in middle school, high school, and beyond (Hill et al., 2005).

Implementing the yearlong, clinical, co-teaching model of student teaching. The positive findings of this study reveal the impact of the yearlong, clinical, co-teaching model of student teaching on student teachers' growth and maturation in elements of effective teaching practices. In implementing the yearlong, clinical, co-teaching model of student teaching, student teachers should be pre-screened and placed into partnerships based on similarities in personality, working style, goals, and/or grade level interest. Additionally, during this pre-screening, student teachers that may not be prepared to successfully complete student teaching can be removed before beginning the program. This may alleviate issues of one partner taking advantage of another. University supervisors need a plan if they discover that one partner student teaching is not doing his/her share of the work, so that it does not act as a detriment to the other student teacher.

Create partnerships between university and local school districts to foster collaboration. Higher education institutions should create partnerships with local school districts to foster collaboration for the creation of yearlong, clinical, co-teaching student teaching programs for all pre-service elementary teachers. Working with local school districts to find school sites willing to host the clinical model of student teaching and recruiting expert master teachers will be critical in the implementation of the yearlong, clinical, co-teaching model of student teaching for elementary pre-service teachers.

Recruited master teachers should be willing to mentor and coach the student teachers (Manzey, 2010; Tobin & Roth, 2005) in order to make the yearlong, clinical, co-teaching model of student teaching advantageous. Additionally, master teachers will need to receive training in coaching partner student teachers and in peer coaching

(Manzey, 2010; Lu, 2010). The partnership between university and local school districts will aid in the design and implementation of the mater teacher training.

School districts. In order to build elementary teachers' PCK to incorporate STEM with CCSS and NGSS to work towards the proposed common vision for education in California, school districts need to implement a STEM-rich professional development program, create curriculum to aid in infusing STEM with CCSS, create a STEM-focused induction program for beginning teachers, create site level learning communities, and provide coaches that specialize in integrating STEM across the curriculum.

Implement STEM professional development program. It is recommended that school districts implement STEM professional development to improve elementary teachers' STEM PCK. The objective of the professional development program should be to provide elementary teachers with in-depth, targeted, ongoing professional development in STEM subjects to impact their instructional practices with STEM subjects. The STEM professional development implemented by school districts should include elements of effective STEM professional development described above because they are based on the findings of this study, the conceptual framework, and other key literature. Additionally, school districts need to plan for vertical alignment within all levels of K–12: elementary, middle, and high school. Professional development will need to be implemented for all teachers in school districts, not only elementary teachers, so students are supported in learning STEM subjects as they progress through the K–12 system.

Create curricula to aid in infusing STEM with CCSS. School districts need to create curricula that integrate STEM with CCSS and NGSS. This curriculum will help elementary teachers integrate STEM because teachers will be given recommendations and suggestions for integrating their curricula and meeting the expectations of CCSS and NGSS. The curriculum should include suggestions for units of study, projects, assessments, and sequencing of curriculum. As shown by this study, elementary teachers need a harmonious and coherent curriculum to support in teaching STEM content.

Create a STEM-focused induction program for beginning teachers. School districts should create STEM-focused induction programs to continue developing STEM-ready elementary teachers. The STEM-focused induction program would create a bridge between teacher preparation programs and practicing teachers while offering continued support and sustainability of STEM. The findings of this study determined that student teachers were willing and excited to teach STEM content in their future classrooms, but that additional support would be required in all four areas of STEM but especially in technology and engineering. The STEM-focused induction program should provide beginning elementary teachers with the opportunity to continue to develop their PCK in all of the STEM areas, focusing on technology and engineering, as well as help beginning elementary teachers infuse STEM with CCSS and NGSS. If STEM is not a focus of induction programs, then beginning teachers are not supported in continuing their development on effectively teach STEM content. By creating STEM-focused induction programs, school districts will impact their beginning teachers' PCK in STEM and help the teachers understand how the reforms of CCSS, NGSS, and STEM support one another and overlap.

Create site level learning communities. In order for professional development to impact teachers' practice, it must be aligned with the principles of adult learning theory in that it is specific, ongoing, and connects to teachers' experiences (Knowles, 1980;

Miroballi, 2010). The findings of this study uncovered that one of the reasons that the STEM professional development was successful was the ongoing collaboration among the student teachers and with the master teachers during and after the professional development sessions. Therefore, in order for school districts to provide professional development on STEM that changes teachers' practice and PCK, there must be follow-up and ongoing support. To do this, school districts should create site level learning communities to continue to develop teachers' understanding of integrating STEM with CCSS and NGSS at the site level. When teachers reflect on their learning from a professional development with their colleagues at their school site, they are able to connect the new learning to their experiences. This aligns with the concepts of orientation of learning and motivation in adult learning theory (Knowles, 1980; Miroballi, 2010). Site level learning communities also build collaboration among teachers, connect the learning with other areas of school change, and are participant-driven; all of these characteristics are found in the literature as elements of effective professional development (Darling-Hammond & McLaughlin, 1995). Additionally, site level learning communities will help teachers connect CCSS, NGSS, and STEM in practice, which is an important aspect of aligning with the proposed common vision for elementary education.

Provide coaches that specialize in integrating STEM across the curriculum. An additional recommendation is for school districts to provide coaches who specialize in STEM integration to work with elementary teachers. The coaches will provide ongoing, targeted professional development for teachers on a one-by-one basis based on the individual teacher's needs. This aligns with the principles of adult learning theory and literature on effective professional development (Darling-Hammond & McLaughlin, 1995; Eilks & Markic, 2011). Coaches can provide resources for teachers, model STEM lessons, help teachers design integrated lessons, and use peer coaching to provide targeted support. Coaches specializing in STEM will aid the school district in preparing all of its elementary teachers to effectively teach STEM subjects and will help the district strive towards the proposed common vision of integrating CCSS, NGSS, and STEM in elementary classrooms. This recommendation supports the findings of this study in that elementary teachers need continued support in teaching STEM content. Several of the participants expressed a wish to see STEM lessons modeled; thus, STEM coaches could be one way to support elementary teachers in teaching STEM subjects.

Research

This study provides opportunities for future research based on its findings and recommendations. Future research can investigate the long-term impact of the program on student teachers once they have their own classrooms. Findings from this study indicate that the student teachers were willing and ready to implement STEM into their future classrooms, so this is an area of interest to research the longitudinal impacts of the STEM-rich, clinical, co-teaching model of student teaching. It would be interesting to find out if this sense of confidence and enthusiasm remains once they have their own classroom and are practicing teachers.

Because the Raising the Bar for STEM Education in California program was a 2-year grant funded program, it is recommended that the program be extended for another 2 years and researched further. Because the findings of the program are positive overall, it would be beneficial to refine the program based upon the identified strengths and weaknesses and then studied again to determine its impact on preparing future elementary teachers to effectively teach STEM subjects. Once the Raising the Bar for STEM Education in California program is researched further, recommendations can be made regarding the dissemination of the program to other universities in California.

Another area of research is on the impact CCSS implementation on STEM efforts. Currently, California and the nation are in the midst of multiple educational reform movements: CCSS, NGSS, and STEM. In this study, findings indicated that the implementation of CCSS interfered with master teachers' willingness to focus on STEM, while student teachers found a convergence between the two reform movements. Research needs to be conducted in the future to learn more about the impact of multiple reforms on teachers and to learn more about the difference in views from master teachers and student teachers regarding CCSS and STEM.

Additionally, future research studies should study the proposed recommendations for policy and practice. The adoption of a yearlong, clinical, co-teaching model of student teaching for all elementary teacher preparation programs in California would be a drastic change for many higher education institutions and, therefore, needs to be researched to determine best practices that can be replicated across institutions. Future research can provide opportunities for higher education institutions to learn from one another in order to provide their students with the PCK in all subject areas, including STEM, to prepare future elementary teachers.

At the school district level, future research on STEM professional development and STEM-focused induction programs will also be necessary in looking at the development of STEM-ready elementary teachers holistically, from preparation programs to induction to experienced teachers. This longitudinal perspective can provide researchers with a deeper understanding of developing PCK in STEM subjects for elementary teachers.

Finally, research needs to be conducted on student achievement and student dispositions towards STEM subjects to learn how providing elementary teachers with professional development in STEM and its integration with CCSS and NGSS impacts students. Conducting research on the influence of teacher professional development during teacher preparation programs, induction, and with experienced teachers on student achievement will add to the knowledge base of research regarding STEM-rich professional development for elementary teachers.

Conclusion

A critical problem in America is that we are not producing enough STEM graduates to meet the needs of society. From 2008 to 2018, it is projected for STEM employment to increase almost twice as fast as all other occupations combined. In a report to President Obama, it was determined that "economic projections point to a need for approximately one million more STEM professionals than the U.S. will produce at the current rate over the next decade" (Olson & Riordan, 2012, p. i). In order to meet the demands of the economy, the STEM pipeline must be expanded in order to educate and produce more STEM graduates.

Research shows that students need to build a foundation for and interest in STEM subjects early in their education, so the STEM pipeline must begin in elementary school. As a result, there is a vital need to prepare elementary teachers to effectively teach STEM subjects to their students. However, most elementary teachers lack the PCK and confidence necessary to teach STEM content. One way to prepare elementary teachers to effectively teach STEM subjects is to provide STEM-focused professional development. This study researched a STEM-rich professional development program for pre-service teachers called the Raising the Bar for STEM Education in California utilizing a case study design. The purpose of this study was to evaluate its effectiveness in preparing future elementary teachers to effectively teach STEM subjects through a STEM-rich, clinical, co-teaching model of student teaching.

This study found that the STEM-rich, clinical, co-teaching model of student teaching was successful because pre-service teachers increased their confidence and expanded their pedagogical knowledge of teaching inquiry-based lessons to build students' conceptual understanding in science and mathematics. Additionally, student teachers were willing and excited to teach STEM subjects in their future elementary classrooms. The program was less successful due to the uneven growth in content knowledge and confidence among the four STEM areas. Student teachers did not feel as comfortable teaching technology or engineering and did not know how to integrate the STEM subjects. Based on the best features of the Raising the Bar for STEM Education in California program, PCK, adult learning theory, and additional literature, it is recommended that future STEM professional development programs to include the following essential elements in order to best impact elementary teachers STEM PCK:

1. Emphasize the importance of STEM fields to the economy and society as the rationale for teaching STEM subjects in elementary classrooms.

2. Build pedagogical content knowledge through focusing on both content and pedagogical strategies.

3. Integrate STEM subjects through focusing on engineering.

4. Explicitly link STEM to Common Core State Standards and Next Generation Science Standards through pedagogical teaching strategies and practices.

5. Develop the foundation of STEM professional development around the characteristics of adult learning theory.

6. Foster reflective, collaborative communities of practice.

Recommendations for policy include creating a unified STEM vision in education in California, modifying multiple subject credential requirements to include STEM, and requiring all teacher preparation programs to adopt a yearlong, clinical, co-teaching model of student teaching. Other recommendations for practice for school districts to sustain PCK in STEM includes providing STEM coaches, creating curriculum to align STEM with CCSS and NGSS, creating STEM-focused induction programs, and creating school site learning communities to further develop STEM PCK for elementary teachers.

This study adds to the knowledge base regarding STEM-rich professional development and STEM-focused student teaching for elementary teachers. The contributions to research in the terms of this study's findings, implications, and recommendations are significant and impact the teaching of STEM subjects in elementary education, which is the start of the STEM pipeline. As CCSS, NGSS, and STEM are implemented, teachers need additional support to effectively teach the new standards and to develop the necessary critical thinking and problem solving skills for success in the 21st century. We must prepare our teachers to effectively teach STEM subjects in alignment with CCSS and NGSS through improved teacher preparation programs and effective professional development. The stakes are high; we cannot let our students down.

APPENDICES

APPENDIX A

INTERVIEW PROTOCOL FOR STUDENT TEACHERS

APPENDIX A

Interview Protocol for Student Teachers

1. Describe your overall student teaching experience this year.
   a. What grade levels did you student teach in?
2. Describe how you and your student teaching partner worked together.
3. How, if at all, was it beneficial for you to have a partner student teacher working with you using a co-teaching model?
   a. Probe: What did you learn from one another?
4. How has your participation in UTEACH and the STEM professional development sessions helped you grow over the past year?
   a. Probe: Provide an example of growth in classroom management.
   b. Probe: Provide an example of growth in lesson/unit planning.
   c. Probe: Provide an example of growth in supporting and engaging all students.
5. After completing your student teaching program, what strengths do you feel you bring to the profession? What are some areas that you need to continue to work on for further growth?
6. What areas of STEM are strengths for you? What areas of STEM are weaknesses for you?
7. What aspects of the STEM-rich student teaching program impacted your STEM content knowledge?
   a. Describe any aspects of the UTEACH student teaching program that built your content knowledge in teaching STEM.

b. Describe any aspects of the after school STEM PD that built your content knowledge in teaching STEM.

8. What aspects of the STEM-rich student teaching program built your confidence in teaching STEM?
    a. Describe any aspects of the UTEACH student teaching program that built your confidence in teaching STEM.
    b. Describe any aspects of the after school STEM PD that built your confidence in teaching STEM.
9. Rate your confidence when teaching STEM content on a scale on 1-10. Explain your rating.
    a. Probe: How has your confidence in teaching STEM changed from the time you started student teaching?
    b. Probe: Give an example of how you have shown confidence in STEM.
10. What could be improved in the STEM-rich student teaching program (both UTEACH and the STEM PD) to better prepare you to be a future elementary teacher with strong STEM content knowledge and confidence?

APPENDIX B

INTERVIEW PROTOCOL FOR MASTER TEACHERS

APPENDIX B

Interview Protocol for Master Teachers

1. Describe your master teaching experience this year.
2. In what ways did the student teachers work together cooperatively as a team?
3. To what extent do you think it was beneficial for the student teachers to have two of them work together using a co-teaching model? Explain.
   a. Probe: Did the student teachers learn from one another? What? How?
4. How have your student teachers grown over the year in the STEM-rich student teaching program?
   a. Probe: Provide an example of growth in classroom management.
   b. Probe: Provide an example of growth in lesson/unit planning.
   c. Probe: Provide an example of growth in supporting and engaging all students.
   d. Probe: Are there any differences in growth in your student teachers?
5. After completing the student teaching program, what strengths do your student teachers bring to the profession? What are some areas that your student teachers need to continue to work on for further growth?
6. What areas of STEM are strengths for your student teachers? What areas of STEM are weaknesses for your student teachers?
7. What aspects of the STEM-rich student teaching program impacted your student teachers' STEM content knowledge?
   a. Describe any aspects of the UTEACH student teaching program that built their content knowledge in teaching STEM.

b. Describe any aspects of the after school STEM PD that built their content knowledge in teaching STEM.

8. What aspects of the STEM-rich student teaching program impacted your student teachers' confidence in teaching STEM?
    a. Describe any aspects of the UTEACH student teaching program that built their confidence in teaching STEM.
    b. Describe any aspects of the after school STEM PD that built their confidence in teaching STEM.
9. Do you believe your student teachers have strong STEM content knowledge and are confident when teaching STEM content? Explain why or why not.
10. What is different about this STEM-rich student teaching experience compared to previous programs?
    a. Probe: Have you observed more STEM teaching and learning this year compared to previous years? Give some examples.
11. What could be improved in the STEM-rich student teaching program to better prepare student teachers to be future elementary teachers with strong STEM content knowledge and confidence?

APPENDIX C

INTERVIEW PROTOCOL QUESTIONS MAPPED TO RESEARCH QUESTIONS AND KEY LITERATURE

APPENDIX C

Interview Protocol Questions Mapped to Research Questions and Key Literature

Interview Protocol Question	Research Question(s)	Literature Reference
1. Describe your overall student teaching experience this year. a. What grade levels did you student teach in?	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Bullough Jr. et al. (2003)
2. Describe how you and your student teaching partner worked together.	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Goodnough et al. (2009) Bullough Jr. et al. (2003)
3. How, if at all, was it beneficial for you to have a partner student teacher working with you using a co-teaching model? a. Probe: What did you learn from one another?	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Goodnough et al. (2009) Bullough Jr. et al. (2003)
4. How has your participation in UTEACH and the STEM professional development sessions helped you grow over the past year? a. Probe: Provide an example of growth in classroom management. b. Probe: Provide an example of growth in lesson/unit planning.	RQ 1	Conceptual Framework: Adult Learning Theory and PCK

c. Probe: Provide an example of growth in supporting and engaging all students.		
5. After completing your student teaching program, what strengths do you feel you bring to the profession? What are some areas that you need to continue to work on for further growth?	RQ 1 RQ 2	Conceptual Framework: Adult Learning Theory and PCK Bullough Jr. et al. (2003)
6. What areas of STEM are strengths for you? What areas of STEM are weaknesses for you?	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Epstein & Miller (2011) Weiss, Banilower, McMahon & Smith (2001)
7. What aspects of the STEM-rich student teaching program impacted your STEM content knowledge? a. Describe any aspects of the UTEACH student teaching program that built your content knowledge in teaching STEM. b. Describe any aspects of the after school STEM PD that built your content knowledge in teaching STEM.	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Epstein & Miller (2011) Weiss, Banilower, McMahon & Smith (2001)

8. What aspects of the STEM-rich student teaching program built your confidence in teaching STEM? a. Describe any aspects of the UTEACH student teaching program that built your confidence in teaching STEM. b. Describe any aspects of the after school STEM PD that built your confidence in teaching STEM.	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Appleton (2003) Dembo & Gibson (1985) Sterling (2006)
9. Rate your confidence when teaching STEM content on a scale on 1-10. Explain your rating. a. Probe: How has your confidence in teaching STEM changed from the time you started student teaching? b. Probe: Give an example of how you have shown confidence in STEM.	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Appleton (2003) Dembo & Gibson (1985) Sterling (2006)
10. What could be improved in the STEM-rich student teaching program (both UTEACH and the STEM PD) to better prepare you to be a future elementary teacher with strong STEM content knowledge and confidence?	RQ 1	Conceptual Framework: Adult Learning Theory and PCK Epstein & Miller (2011) Appleton (2003) Dembo & Gibson (1985)

APPENDIX D

VIDEOTAPED LESSON REFLECTION FORM

APPENDIX D

Videotaped Lesson Reflection Form

Self-Evaluation of Videotaped Lesson

!!!!!!!!!!!!!!!!!!!!!!!! !

Student Teacher ____ Date: ________________________________

Lesson Topic: ____ Grade/Class ______________________

Length of lesson _________Master Teacher: __________________ Supervisor: _________________________

Instruction	Effective	Satisfactory	Needing Improvement
1. Introduction to Lesson			
2. Development of lesson objective			
3. Engagement of Students			
4. Modification to meet needs of Special Needs			
5. Maximizing opportunities for participation			
6. Provided feedback to all learners			
7. Encouraged higher-order thinking			
8. Use of Instructional time			
9. Use of available resources			
Comments:			

Classroom Management	Effective	Satisfactory	Needing Improvement
1. Created and maintained a positive learning climate			
2. Managed routines and transitions			
3. Established behavioral expectations			
4. Maintained positive methods for handling behavior			
Comments:			

APPENDIX E

5E LESSON PLAN FORMAT

APPENDIX E

5E Lesson Plan Template

California Science Content Standards
Specific Learning Objectives
Materials
ENGAGE • Describe how the teacher will capture students' interest. • What kind of questions should the students ask themselves after the engagement?
EXPLORE • Describe what hands-on/minds-on activities students will be doing. • List "big idea" conceptual questions the teacher will use to encourage and/or focus students' exploration
EXPLAIN • Student explanations should precede introduction of terms or explanations by the teacher. What questions or techniques will the teacher use to help students connect their exploration to the concept under examination? • List higher order thinking questions which teachers will use to solicit *student* explanations and help them to justify their explanations.
ELABORATE • Describe how students will develop a more sophisticated understanding of the concept. • What vocabulary will be introduced and how will it connect to students' observations? • How is this knowledge applied in our daily lives?
EVALUATE • How will students demonstrate that they have achieved the lesson objective? • This should be embedded throughout the lesson as well as at the end of the lesson

1

APPENDIX F

PEER COACHING FORM

APPENDIX F

Peer Coaching Form

- **All student teachers need to complete one log a week.**
- **Review the comments with your supervisor at your regularly scheduled observation times.**

Peer Coaching Log

Coach: ____ **Date:** ___________________________

Signature of Observed Teacher Candidate ____

Lesson Name (or Focus)____________________________________ ___________________________

Lesson Evaluation:

Directions: Determine the major area of focus for your observation. Check that box.	
☐ Input/Guided Practice	☐ Uses Cooperative Learning methods
☐ Uses Higher Level Questioning strategies	☐ Materials well prepared, organized & accessible
☐ Uses SDAIE strategies	☐ Includes an assessment component
☐ Pacing/timing/transitions appropriate	☐ Other -

Strengths:
Cite strengths of lesson based on focus.
Give examples in measurable terms
Talk with partner about notes.

Recommendations:
Cite recommendations
Give examples for change
Ask Supervisor/Master Teacher to read comments.

APPENDIX G

SCIENCE EFFICACY BELIEFS INSTRUMENT (STEBI)

APPENDIX G

Science Teaching Efficacy Belief Instrument*

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree
A = Agree
UN = Uncertain
D = Disagree
SD = Strongly Disagree

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA A UN D SD
2.	I am continually finding better ways to teach science.	SA A UN D SD
3.	Even when I try very hard, I don't teach science as well as I do most subjects.	SA A UN D SD
4.	When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.	SA A UN D SD
5.	I know the steps necessary to teach science concepts effectively.	SA A UN D SD
6.	I am not very effective in monitoring science experiments.	SA A UN D SD
7.	If students are underachieving in science, it is most likely due to ineffective science teaching.	SA A UN D SD
8.	I generally teach science ineffectively.	SA A UN D SD
9.	The inadequacy of a student's science background can be overcome by good teaching.	SA A UN D SD
10.	The low science achievement of some students cannot generally be blamed on their teachers.	SA A UN D SD
11.	When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.	SA A UN D SD
12.	I understand science concepts well enough to be effective in teaching elementary science.	SA A UN D SD
13.	Increased effort in science teaching produces little change in some students' science achievement.	SA A UN D SD
14.	The teacher is generally responsible for the achievement of students in science.	SA A UN D SD
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	SA A UN D SD
16.	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	SA A UN D SD
17.	I find it difficult to explain to students why science experiments work.	SA A UN D SD
18.	I am typically able to answer students' science questions.	SA A UN D SD
19.	I wonder if I have the necessary skills to teach science.	SA A UN D SD
20.	Effectiveness in science teaching has little influence on the achievement of students with low motivation.	SA A UN D SD
21.	Given a choice, I would not invite the principal to evaluate my science teaching.	SA A UN D SD
22.	When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	SA A UN D SD
23.	When teaching science, I usually welcome student questions.	SA A UN D SD
24.	I don't know what to do to turn students on to science.	SA A UN D SD
25.	Even teachers with good science teaching abilities cannot help some kids learn science.	SA A UN D SD

*In Riggs, I., & Knochs, L. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

APPENDIX H

MATHEMATICS TEACHING EFFICACY BELIEFS INSTRUMENT (MTEBI)

APPENDIX H

Mathematics Teaching Efficacy & Beliefs Instrument

This instrument was designed by mathematics educators to measure some of your feelings about mathematics teaching.
Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = STRONGLY AGREE
A = AGREE
UN = UNCERTAIN
D = DISAGREE
SD = STRONGLY DISAGREE

1. When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort.	SA A UN D SD
2. I will continually find better ways to teach mathematics.	SA A UN D SD
3. Even if I try very hard, I will not teach mathematics as well as I will most subjects.	SA A UN D SD
4. When the mathematics grades of students improve, it is often due to their teacher having found a more effective teaching approach.	SA A UN D SD
5. I know the steps necessary to teach mathematics concepts effectively.	SA A UN D SD
6. I will not be very effective in monitoring mathematics activities.	SA A UN D SD
7. If students are underachieving in math, it is most likely due to ineffective math teaching.	SA A UN D SD
8. I will generally teach math ineffectively.	SA A UN D SD
9. The inadequacy of a student's mathematics background can be overcome by good teaching.	SA A UN D SD
10. The low achievement of some students cannot generally be blamed on their teachers.	SA A UN D SD

11. When a low-achieving child progresses in mathematics, it is usually due to extra attention given by the teacher.	SA A UN D SD
12. I understand mathematics concepts well enough to be effective in teaching math.	SA A UN D SD
13. Increased effort in mathematics teaching produces little change in some students' mathematics achievement.	SA A UN D SD
14. The teacher is generally responsible for the achievement of students in mathematics.	SA A UN D SD
15. Students' achievement in mathematics is directly related to their teacher's effectiveness in mathematics teaching.	SA A UN D SD
16. If parents comment that their child is showing more interest in mathematics at school, it is probably due to the performance of the child's teacher.	SA A UN D SD
17. I will find it difficult to use manipulatives to explain to students why mathematics works.	SA A UN D SD
18. I will typically be able to answer students' mathematics questions.	SA A UN D SD
19. I wonder if I will have necessary skills to teach mathematics.	SA A UN D SD
20. Effectiveness in mathematics teaching has little influence on the achievement of students with low motivation.	SA A UN D SD
21. Given a choice, I will not invite the principal to evaluate my mathematics teaching.	SA A UN D SD
22. When a student has difficulty understanding a math concept, I will usually be at a loss as to how to help the student understand it better.	SA A UN D SD
23. When teaching mathematics, I will usually welcome student questions.	SA A UN D SD
24. I do not know what to do to turn students on to mathematics.	SA A UN D SD

25. Even teachers with good mathematics teaching abilities cannot help some kids to learn mathematics.	SA A UN D SD

APPENDIX I

INFORMED CONSENT FOR MASTER TEACHERS

APPENDIX I

Informed Consent for Master Teacher

CONSENT TO PARTICIPATE IN RESEARCH:
MASTER TEACHER

Preparing Future Elementary Teachers with a STEM-Rich, Co-Teaching Model of Student Teaching

You are being invited to participate in a research study conducted by Stacey Benuzzi under the supervision of Dr. Linda Symcox from the Department of Educational Leadership. You were selected as a possible participant in this study because you are participating in the UTEACH STEM professional development program sponsored by the S.D. Bechtel, Jr. Foundation as a master teacher at Cleveland Elementary.

PURPOSE OF THE STUDY

The purpose of this study is to explore how a STEM-rich, co-teaching model of student teaching prepares future elementary teachers and to learn about student teachers' content knowledge and confidence in teaching STEM content.

PROCEDURES

If you volunteer to participate in this study, you will do the following things, all taking place at Cleveland Elementary.

1. Be interviewed by the researcher regarding your perspective of your student teacher(s) experiences and preparation in teaching STEM (interviews will be audio recorded)
2. You are not required to participate in the study if you choose not to. You will still be entitled to all of the incentives built into the grant program and you will remain a full participant in all other grant activities.

POTENTIAL RISKS AND DISCOMFORTS

There are no major risks or hazards if you participate in this research component of the grant. Since your name will remain anonymous in any write-up of the project, you should not be worried about being identified. You are assured that any results will not be used for evaluative purposes and will not be shared with university, school, or district administration. Additionally, you may choose not to respond to any question that makes you feel uncomfortable or choose to discontinue your participation at any time without any negative consequences. Finally, data will be stored in a locked file cabinent in Stacey Benuzzi's home and/or on password protected computer in password protected files.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

You will possibly benefit from the research by reflecting on your own growth during your master teaching experience and the growth of your student teacher(s)' teaching.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

Results from the analysis of the interviews will be summarized in reports given to the S.D. Bechtel, Jr. Foundation and for research publication. All names will remain confidential.

Data will be stored in a locked file cabinent in Stacey Benuzzi's home and/or on a password protected computer in password protected files.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. Since your name will remain anonymous in any write-up of the project, you should not be worried about being identified. You are assured that any results will not be used for evaluative purposes and will not be shared with university, school, or district administration. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. Finally, data will be stored in a locked file cabinent in Stacey Benuzzi's home and/or on password protected computer in password protected files.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Stacey Benuzzi at XXX-XXX-XXXX or via email: XXX@csulb.edu or Dr. Linda Symcox at 562-985-1147 or via email: linda.symcox@csulb.edu.

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact the Office of University Research, CSU Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840; Telephone: (562) 985-5314 or email to research@csulb.edu.

SIGNATURE OF RESEARCH SUBJECT

I understand the procedures and conditions of my participation described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Printed Name of Subject ______________________________

Signature of Subject ______________________________ Date ____________________

Please initial on the following lines if you agree to the medium that will be utilized in this study:

Audio recording ______ Interview ______

APPENDIX J

INFORMED CONSENT FOR STUDENT TEACHERS

APPENDIX J

Informed Consent for Student Teacher

CONSENT TO PARTICIPATE IN RESEARCH:
STUDENT TEACHER

Preparing Future Elementary Teachers with a STEM-Rich, Co-Teaching Model of Student Teaching

You are being invited to participate in a research study conducted by Stacey Benuzzi under the supervision of Dr. Linda Symcox from the Department of Educational Leadership. You were selected as a possible participant in this study because you are participating in the UTEACH STEM professional development program sponsored by the S.D. Bechtel, Jr. Foundation as a student teacher at Cleveland Elementary.

PURPOSE OF THE STUDY

The purpose of this study is to explore how a STEM-rich, co-teaching model of student teaching prepares future elementary teachers and to learn about student teachers' content knowledge and confidence in teaching STEM content.

PROCEDURES

If you volunteer to participate in this study, you will do the following things, all taking place at Cleveland Elementary.

1. Create lesson plans on STEM content
2. Keep a journal about your student teaching experience
3. Offer peer-to-peer support through peer coaching activities
4. Videotape yourself teaching one STEM lesson
5. Meet with the researcher to do a video debrief of your lesson (interviews will be audio recorded)
6. You are not required to participate in the study if you choose not to. You will still be entitled to all of the incentives built into the grant program and you will remain a full participant in all other grant activities.

POTENTIAL RISKS AND DISCOMFORTS

There are no major risks or hazards if you participate in this research component of the grant. Since your name will remain anonymous in any write-up of the project, you should not be worried about being identified. You are assured that any results will not be used for evaluative purposes, and will not be shared with university, school, or district administration. Additionally, you may choose not to respond to any question that makes you feel uncomfortable or choose to discontinue your participation at any time without negatively affecting your employment. Finally, data will be stored in a locked file cabinent in Stacey Benuzzi's home and/or on password protected computer in password protected files.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

You will possibly benefit from the research by reflecting on your own learning and growth during your student teaching experience and the research process.

You will possibly benefit by learning from and reflecting on your lesson plans, journal writings, peer coaching, and videotaped lesson.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. All names on the lesson plans, journal entries, and peer coaching forms will be removed by Joan Wilkes (university supervisor) before they are given to the researcher to enhance confidentiality and anonymity.

Results from the analysis of the lesson plans, journal entries, video debrief, and/or peer coaching will be summarized in reports given to the S.D. Bechtel, Jr. Foundation and for research publication. All names will remain confidential.

Data will be stored in a locked file cabinent in Stacey Benuzzi's home and/or on a password protected computer in password protected files.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. Participation or non-participation will not affect your teacher preparation program or student teaching grade/evaluation. You may also refuse to answer any questions you don't want to answer and still remain in the study.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Stacey Benuzzi at XXX-XXX-XXXX or via email: XXX@csulb.edu or Dr. Linda Symcox at 562-985-1147 or via email: linda.symcox@csulb.edu.

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact the Office of University Research, CSU Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840; Telephone: (562) 985-5314 or email to research@csulb.edu.

SIGNATURE OF RESEARCH SUBJECT

I understand the procedures and conditions of my participation described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Printed Name of Subject ________________________________

Signature of Subject ________________________________ Date ____________________

Please initial on the following lines if you agree to the medium that will be utilized in this study:

Audio recording ______ Visual (tape recording) ______ Interview (video debrief) _______

APPENDIX K

RATIONALE FOR THE RECOMMENDED ESSENTIAL ELEMENTS OF EFFECTIVE STEM PROFESSIONAL DEVELOPMENT

APPENDIX K

Rationale for the Recommended Essential Elements of Effective STEM Professional Development

Features	Description	Rationale
Goals	Improve elementary teachers' pedagogical content knowledge and confidence in teaching STEM subjects	Literature review
	Increase the time spent on teaching STEM subjects in elementary classrooms	Literature review
Design	Yearlong professional development program with bimonthly meetings	Literature review
Components	Emphasize the importance of STEM to the economy and society as the rationale for teaching STEM subjects in elementary classrooms	Findings of study Literature review
	Build pedagogical content knowledge through focusing on both content and pedagogical strategies	Findings of study Conceptual Framework Literature review
	Integrate STEM subjects through focusing on engineering	Findings of study
	Explicitly link STEM to Common Core State Standards and Next Generation Science Standards through pedagogical teaching strategies and practices	Findings of study
	Develop the foundation of STEM professional development around the characteristics of Adult Learning Theory	Findings of study Conceptual Framework
	Foster reflective, collaborative communities of practice	Findings of study Literature review

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