TEACHING THE NEXT GENERATION OF SCIENTISTS:
SCIENCE EDUCATION IN THE PRIMARY GRADES

by

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Abstract

This study examined the conduct of primary grade science education in two school districts in Central California in order to identify opportunities for improvement, which, if generalized to systemic levels, may have the potential to positively impact student achievement and participation in STEM fields. The shortage of STEM-qualified workers has been of significant economic and strategic concern for decades, sparking scores of programs intended to address this persistent shortage. Teams of scientists and educators have developed effective science education curricula over the past six decades, but as education policy shifts and accountability models change, these programs, even when proven effective, fall out of favor and use.

Data mining was used to gather information regarding current levels of science achievement among students in Grades 5 to 10. A mixed methods design was used to gather data regarding the science content knowledge, pedagogical content knowledge and self-efficacy for teaching science of teacher participants. Quantitative data appeared to show that the variables of content knowledge and pedagogical content knowledge did not have a significant effect on the self-efficacy for teaching science of participants. Qualitative data appeared to demonstrate an affinity for teaching science among participants, but that classroom activities purported to be science education were more oriented toward
English/Language Arts education possibly due to accountability model constraints which place greater emphasis on English/Language Arts and Mathematics achievement over other curricular areas. Transcripts of qualitative data are contained in Appendices B and C. Additionally, teacher participants reported during interviews to feeling less prepared to teach science during undergraduate preparation and teacher education programs than for teaching other subjects, which may indicate lower self-efficacy for teaching science, and possible reasons for this decreased self-efficacy. Further, teacher participants expressed concerns regarding a perceived lack of resources to teach science, and eagerness for additional professional development opportunities that conform with the best practices of adult learning theory.
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It seems like the last few years of my life have passed at warp speed. Between taking care of my children, which involved supporting the elder in negotiating college attendance and life in a metropolis far from home and his progress down the path to independent adulthood, and the younger through her high school activities, the requisite proms, SATs, college applications and the anxiety-ridden selection process, to be followed then by graduation and moving away to said college, and my own work and school commitments, I wouldn’t have placed bets that I would be writing this section of my dissertation now. Being one disinclined to self-aggrandizing or self-congratulatory behavior, it seems altogether fitting and rather brilliant to me that this section is included in a dissertation because it requires reflection upon the process and how one arrived at the point of even thinking about composing these acknowledgements. Completing a project like this dissertation has not been a solo journey.

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CHAPTER 1: INTRODUCTION

The emphasis on achievement in the fields of science, technology, engineering and math (STEM) has shifted in recent decades from being solely an issue of national security, as it was during the Cold War, to becoming a combination of security and efforts to maintain primacy in global economic markets. Economies are becoming more dependent on the ability of workers to design and implement concept solutions to the many resource challenges that are becoming more common as populations and demands on raw materials increase and industries evolve and emerge (National Science Board, 2010). Although the federal government has implemented many reform programs designed to increase the numbers of workers in STEM fields over the past six decades, the nation continues to experience critical shortages of workers in these areas (Chen & Soldner, 2013; National Science Board, 2007). For many years, foreign nationals filled the manpower void in STEM fields, but as the economies of other countries have become more developed, recruitment of these workers by foreign entities has increased, resulting in greater competition for the finite resource of qualified STEM workers (Broughton, 2013; Zhang & Barnett, 2013).

Maintenance of the level of innovation necessary to ensure continued economic growth is dependent on effective teachers in an educational system that is able to produce workers who possess the ability to persevere through challenges and who think both creatively and analytically (Broughton, 2013; Darling-Hammond, 2000, National Science Board, 2010). Production of workers with such skills must be accomplished while supporting the development of the human capital potential of all citizens and prospective workers, which places a heavy burden upon schools. To support these efforts, the United States government has
invested significantly in science education. In 2010, the federal government spent $3.4 billion to support research and science education programs (White House Office of Science and Technology Policy, 2011, p. 2), yet the results of the 2012 Programme for International Assessment (PISA) administered by the Organisation for Economic Cooperation and Development (OECD) showed that the performance of U.S. students has remained static over the past decade (OECD, 2013). Increasing the science content knowledge and science pedagogical content knowledge of teachers in the primary grades may improve the self-efficacy of teachers in science education and result in gains in student achievement in STEM fields.

**Purpose of the Study**

The purpose of this study was to investigate current levels of self-efficacy for teaching science among primary grade teachers in two suburban school districts in Central California. Self-efficacy for teaching science may originate from various sources, including experiences prospective teachers encounter over the course of their compulsory education. Undergraduate preparation and credentialing programs may also contribute to the self-efficacy for teaching science of prospective teachers, while professional development activities may influence the self-efficacy for teaching science of in-service teachers. The dependent variables in this study were current levels of science teaching self-efficacy and the conduct of science education in primary grade classrooms. The independent variables were content knowledge and pedagogical content knowledge acquired through science course completion during undergraduate preparation and credentialing programs, and demographic information. The goal of this study was to collect sufficient data regarding the effects of undergraduate preparation and teacher education programs on teacher self-efficacy for teaching
science in order to inform policy adjustments in science teaching in the primary grades. Such adjustments may present a means of increasing student achievement and participation in STEM fields.

**Research Questions**

Educators are in a period of transition between standards-based education to a more constructivist-oriented approach required by the adoption of Common Core State Standards (CCSS) (Hopper, 2013; Kamii, 2015). Economic concerns regarding maintenance of global competitiveness add an additional layer of concern, and place particular emphasis on increased participation in STEM fields. Many science education researchers have focused on two issues: the amount and frequency with which students are exposed to the sciences during the formative years of the early grades, when greater emphasis is placed on ELA and Math instruction than Science, and the self-efficacy of elementary school teachers regarding their science content knowledge and pedagogical content knowledge. The body of literature exploring these issues informs the following research questions:

- **RQ1**: What is the practice of teaching science in the primary grades?
- **RQ2**: How do content knowledge, pedagogical content knowledge and other teacher variables relate to primary teachers’ self-efficacy for teaching science?

**Background**

Previous incarnations of STEM reforms such as the National Defense Education Act of 1958 were closely associated with Cold War politics, fueled by ideological differences and fear of possible military action. Current STEM reform initiatives are oriented more toward maintenance of a dominant global economic
position by focusing on the nexus of STEM and economics, and the preparation of workers for these fields. Eminent scientist and science education advocate Neil deGrasse Tyson remarked on the topic at a recent press conference held at the American Museum of Natural History (Sundermier, 2016). In his remarks, he compared the condition of STEM education in the United States to attempting to sail in the doldrums, the areas of the Earth’s surface with insufficient wind power to continue moving forward. Tyson stated, “Everything we know about science and technology tells us that they are the engines of future economies. They are the seeds of tomorrow’s growth of wealth…If you don’t want to die poor you should invest in STEM” (as cited in Sundermier, 2016).

Over the past three decades, an increased cultural emphasis on STEM education has emerged, perhaps in response to perceptions of learning deficits in these areas, fueled by reports such as *A Nation at Risk: The Imperative for Educational Reform* (National Commission on Excellence in Education, 1983). Such emphasis may be evidenced by the passage of legislation mandating science achievement assessment, such as the NCLB in 2002 and its subsequent reauthorizations, including the Every Student Succeeds Act of 2015, and the multiple STEM initiatives embarked upon by the Obama administration (White House Office of Science and Technology Policy, 2016). Efforts to exploit emerging markets has spurred significant changes in how people interact with science and technology, particularly with the exponential growth of social media, and resulted in development and adoption of technology education standards concurrent with a push to infuse instruction with technology (California Department of Education [CDE], 2014c; Change the Equation, 2015; Stosic, 2015). In chapter 10 of the *English Language Arts/English Language Development Framework for California Public Schools Kindergarten through*
Grade Twelve, the California State Board of Education defined 21st century learning as the “need to acquire the cognitive and social skills and dispositions that enable them [students] to succeed in the dynamic, fast-paced, and complex world of the 21st century” (CDE, 2014c, p. 938). The Board emphasized the importance of technology, asserting that “Technology pervades modern society. It impacts most aspects of the…lives of youth and adults…The question is not whether technology should be used in classrooms, but rather how best to capitalize on technology to support teachers and learners” (CDE, 2014c, pp. 954-955).

In order to examine the effects of STEM education on the California economy, the CDE analyzed employment data for all types of available jobs within the state (California Department of Education, 2016a). The study found that for each available job in the state, there were five job applicants, indicating an overall competitive job market. However, when employment statistics in STEM fields were disaggregated from the data, the results were reversed. According to the CDE, for each person seeking a job in a STEM field, there were one-and-a-half jobs available, further illustrating the existence of a deficit of workers in STEM fields which may affect the state’s economy (CDE, 2016a). In his 2016 State of the Union address, President Obama discussed the connection between STEM fields and employment, stating “In the coming years, we should build on that progress, by … offering every student the hands-on computer science and math classes that make them job-ready on day one” (Obama, 2016, as cited in White House Office of Science and Technology Policy, 2016, p. 1). STEM fields and STEM education reform has received much attention due to political events, cultural evolution, and the impact of innovation on world economies.

Such attention is not a new development, but rather the latest variation of an old story of education reform. In Tinkering toward utopia: A century of public
school reform (1995), Stanford University historians David Tyack and Larry Cuban provided a history of school reform movements. These authors posited that education reforms have followed a predictable and iterative three-stage process, and that the who, the what, and the how may have changed over repeated cycles, but that the cycle stages of policy talk, policy action and policy implementation remain constant. Tyack and Cuban (1995) pointed out that “Reform of instruction by remote control has rarely worked well” (p. 135), and advocated for greater inclusion of teachers in development of education policy, stating,

To the degree that teachers are out of the loop on policy reforms, it is not surprising if they drag their feet in implementing them. Teachers do not have a monopoly on educational wisdom, but their first-hand perspectives on schools and their responsibility for carrying out official policies argues for their centrality in school reform efforts. As “street-level bureaucrats,” teachers typically have sufficient discretion, once the classroom doors close, to make decisions about pupils that add up over time to de facto policies about instruction, whatever the official regulations. In any case, then, teachers will make an imprint on education policy as it becomes translated into practice. (p. 135)

Tyack and Cuban (1995) acknowledged that unless teachers understand and support reform efforts, no matter how well planned, implemented, trained and supported reform initiatives are, they will likely be unsuccessful.

This statement is strongly related to the work of DuFour and Fullan (2013) regarding the differences between the adopted curriculum, the implemented curriculum, and the assessed curriculum, and how differences among these versions of curricula affect student learning and may contribute to achievement gaps. The categories presented by DuFour and Fullan of adopted curriculum, implemented curriculum, and the assessed curriculum appear to closely relate to the cycle of policy talk, policy action and policy implementation proposed by Tyack and Cuban (1995). Further, it appears that gaps in science teaching and
learning have been acknowledged in the policies of the Obama administration regarding STEM teacher preparation and training. In the 2017 budgetary and guidance policy documents for STEM education, the administration continued to support the 100K in 10 initiative to prepare and place 100,000 new highly-qualified STEM educators in classrooms by 2020, proposed the creation of a STEM master teacher corps, and committed to leveraging material and intellectual assets possessed by government agencies such as the National Oceanic and Atmospheric Administration (NOAA) for teacher professional development (White House Office of Science and Technology Policy, 2016).

**Science and the Cultural Zeitgeist**

One significant cultural change in public education has been the advent of programs and entire channels devoted to educational pursuits. For many years, educational programming was relegated to the Public Broadcasting System (PBS), as astrophysicist Carl Sagan’s seminal science education program *Cosmos* was when it premiered in 1980. Since then, science and science education has become mainstream, as evidenced by the success of The Discovery Channel© and its associated group of cable channels, which have experienced considerable growth since its inception in the 1990s as measured by viewer ratings gathered by Statista (2015). Programming on this channel often places in the top 10 most-viewed cable channels, ahead of other popular channels such as The Food Network, HGTV and The History Channel. Further proof of the trending popularity of science can be found in the reincarnation of *Cosmos* in 2015 on Fox Broadcasting Company, and a remake of PBS’ *The Magic School Bus* science program planned for broadcast by Netflix in 2016 (Gibson, 2014). Following science education pioneer Bill Nye, a new generation of science education advocates such as astrophysicist Neil deGrasse Tyson and theoretical physicist Michio Kaku has
emerged and become part of the cultural mainstream, appearing in multiple science-oriented television programs and commercials for various products. Massive open online courses (MOOCs) in STEM fields have become widely available with the advent of increased internet access and applications development, and tutorial programs such as the Khan Academy provide assistance to learners in a wide array of subjects (Khan Academy, 2016). The visibility of science fields and the accessibility of STEM education resources have increased significantly.

Accompanying the science trend in television, the motion picture industry has contributed to increased awareness of science through its products. The struggles and triumphs of STEM luminaries such as John Nash (A Beautiful Mind, 2001), Stephen Hawking (The Theory of Everything, 2014) and the team behind the triumphant return of the Apollo 13 mission crew to Earth provided content for successful films. The contribution of science to the genre of science fiction as support for a good story and the appealing visual art provided by special effects has resulted in significant financial success for many franchise films, such as Star Wars, Star Trek, Jurassic Park, and Transformers. Elements from many films in the science fiction genre have become culturally embedded, such as the revelation of Luke Skywalker’s paternity, or that an issue has arisen of which Houston must be informed. Such science-oriented content is not a new phenomenon; television programs with a STEM orientation have been ubiquitous since the inception of the television industry – Lost in Space, The Six-Million Dollar Man, Battlestar Galactica, medical dramas such as Quincy, M.E. and ER, and the CSI and Star Trek program suites are only a few examples of how pervasive science in some form has been in our society over the past 50 years. It can be argued that interest in STEM fueled the significant growth in popularity of another media form, the
comic book industry, and fueled the enterprises around its various conventions, for after all, without all the accompanying science and technology, Bruce Wayne and Tony Stark are just two more millionaire playboys.

In addition to media programming, celebrities have spoken in support of STEM education, even as the long-running television show *The Big Band Theory* perpetuates negative stereotypes of scientists and engineers by portraying them as awkward and maladjusted (Sheehy, 2013). Some celebrities are focused on using their star power to increase interest in STEM fields among girls. Mayim Bialik, who stars as a neuroscientist in the aforementioned *The Big Bang Theory*, has worked with the National HerWorld program to increase interest in science among high-school-aged girls (Sheehy, 2013). Golden Globe Award®-winning actress, writer and comedian Amy Poehler started a website (amysmartgirls.com) dedicated to encouraging girls to be more creative and curious about science and the world around them rather than focused on conformity. Actress Danica McKellar (*The Wonder Years*) has written several books, including *Kiss My Math: Showing Pre-Algebra Who’s Boss* (2008), aimed at increasing girls’ interest and achievement in Math. Since participating in the production of *Apollo 13* (1995), actor Tom Hanks and director Ron Howard have supported progress in space science through their work on films featured at the Kennedy Space Center. Many other celebrities support environmental causes such as access to potable water and protests against strip mining, or medical causes such as vaccination and access to mosquito nets in areas affected by malaria (Charity Navigator, n.d.).

The field of computer science education has a high-profile supporter in Facebook Chief Executive Officer Mark Zuckerberg, who appeared in tutorial support videos for the technology education website code.org (code.org, n.d.). The site offers computer coding education activities for children beginning from a
very young age in order to develop interest in the field. Toys, such as Tinker Toys® and Erector® sets, aimed at increasing children’s interest in engineering have been available for almost a century, and the emphasis on science education during the Cold War resulted in the production of some interesting toy products, such as the Gilbert U-238 Atomic Energy Lab, complete with authentic uranium ore (Gajitz, n.d.). A recent wave of education reform spawned an entire franchise specializing in learning toys. Zany Brainy, a division of toy retailer FAO Schwartz, operated throughout most of the 1990s before going bankrupt in 2001 (Ho, 2001).

More recently, a female engineer started GoldieBlox®, a toy company with the stated goal of increasing the participation of women in engineering (GoldieBlox, 2015). GoldieBlox® received much attention when the company’s commercials, featuring young girls using the company products to break gender stereotypes regarding engineering, aired during the 2014 Super Bowl (Kavilanz, 2014). These commercials encouraged girls to “rock” their toys with jingle lyrics of “We’re more than pink, pink, pink; we want to think!” (GoldieBlox, 2015). Efforts at increasing STEM interest and participation among the young abound and appear to cut across many segments of industry, but, when the onslaught of STEM initiatives is put into conversation with the continuing issues with STEM participation, the reasons behind the persistence of low participation levels and low achievement is ripe for examination, particularly in light of the recent adoption of the Next Generation Science Standards (NGSS).

The NGSS were the product of a Carnegie Foundation commission to improve the achievement of U.S. students in STEM fields through increased rigor and depth of fewer standards and systemic professional development to improve instruction and curriculum development (Carnegie Corporation of New York and
Recent scholarship in the area of science education has focused on the preparation of elementary teachers as a means of increasing participation and persistence in STEM fields by raising the content knowledge and pedagogical content knowledge of these educators.

**Significance of the Study**

This study proposed to investigate the science content knowledge acquired through undergraduate preparation and pedagogical content knowledge gained during completion of credentialing programs on the self-efficacy of primary grade teachers in teaching science, and the connection between science teaching self-efficacy and student achievement. Lower self-efficacy in teaching science may lead to fewer opportunities for students to engage with science content and contribute to lower levels of student engagement and participation. Increasing the undergraduate science education requirements for prospective teachers may result in higher rates of science teaching self-efficacy and increased student engagement, participation and achievement in STEM fields. Research in the area of science education for elementary-age students appears to show that children as young as kindergarten are already developing ideas of what science is and whether or not they are “good” at it (Hill, Corbett, & St. Rose, 2010; Kahle, 1985, Kelly, 1987). Chambers (1983) developed the Draw a Scientist Test (DAST) that was administered to nearly 5,000 primary grade children in the United States, Canada and Australia. Afterward, the drawings were analyzed for common attributes. The majority of young children participating in Chambers’s DAST investigation perceived “scientists” as male, older and white - characteristics that were not reflective of the children’s identities. Further, the drawings may have demonstrated that these kindergarten students already perceived themselves as not being scientists. In a study of students up to Grade 10, Ebenezer and Zoller (1993)
found that students’ attitudes toward STEM fields declined over the course of their compulsory education. The majority of the research in increasing STEM participation and achievement has focused on high school and post-secondary education, but by increased emphasis on science education in primary classrooms, teachers of young students may play a significant role in remedying the STEM crisis.

**Theoretical Framework**

Two theoretical frameworks informed this inquiry: self-efficacy and adult learning theory.

**Self-efficacy**

Self-efficacy was described in Bandura’s (1977) seminal work as the belief that intentional action taken toward a specific goal can lead to a desired outcome. Following this reasoning, if the declared goal of current initiatives and programs is to increase STEM participation, subsequent appropriate actions should follow in order to meet this goal. Researchers have examined the STEM deficit from many perspectives, such as gender, ethnicity and race, socioeconomic status, and parent education level. Each of these factors has a supporting body of research which informed policies and resulted in programs designed to address the specific issues contributing to the dearth of STEM participation based on the focus factor. The academic preparation of teachers of science in the primary grades is a newer topic of attention in the research, and primary teachers may be in the strongest position of all teachers to make lasting contributions to solve the STEM crunch through their daily classroom practice. Increasing the self-efficacy of such teachers in both science knowledge and ability to deliver science content, while placing greater emphasis on science education in the primary grades, has the potential to increase
student interest and lay foundational skills for further achievement in the sciences, and can easily be implemented through changes to teacher education programs and increased scrutiny of the implemented curriculum by Local Education Agencies (LEAs).

**Adult Learning Theory**

Adult learning theory should inform professional development and learning opportunities should conform to the tenets of Knowles’ (1962, 1972, 1974) work in this area. Knowles (1974) posited that adults learn best when instruction is self-directed, purposeful, considerate of prior knowledge, and relevant to the adult learner’s needs. He asserted that adults learn differently from children, and used the term *andragogy* to describe the processes by which adults learn, in contrast to *pedagogy*, which is the process by which children learn. In *The Role of Adult Education in the Public Schools* (1962), Knowles traced the evolution of adult education as the purpose of an adult education model changed from providing compulsory education for youth who by exigency worked during the day, to one of indoctrination into American culture during immigration surges, and finally to the contemporary continuing education role that many associate with adult education. Knowles (1962) was almost prescient regarding the expansion of adult education, and posited that teachers’ roles in the process of education should shift from “‘one who primarily transmits knowledge’ to ‘one who primarily helps students to inquire’” (p. 33). While Knowles did not discount the importance of subject matter content knowledge, he placed great emphasis on the pedagogical knowledge of teachers, viewing skill in “guiding (and serving as a resource to) students in conducting self-inquiries” as essential to facilitating constructive learning experiences in all subject areas (Knowles, 1962, p. 33). Knowles (1962) regarded learning as a life-long process, transitioning when developmentally
appropriate from pedagogy to andragogy, as evidenced by this statement, “if man is to avoid becoming obsolete, it must come to pass that the normal day of every adult will include several hours of systematic learning…’Going to school’ will become …accepted [as] a part of the adult role in society” (p. 34). In pursuit of the creation of life-long learners, he considered teaching students how to learn far more important than ingraining a collection of facts.

In “The Manager as Educator,” Knowles (1972) posited that the managers who are best able to develop the human capital of their employees make the most significant contribution to corporate success, and asserted that in modern management theory, “every manager must be an educator, too” (p. 98). Additionally, Knowles (1972) contended that managers who acknowledge that adult learners are self-directed create a working environment in which workers feel respected and autonomous in determining professional development needs. As Knowles (1972) stated, “the learnings which an adult is most highly motivated to do something about are the ones he diagnoses as needing himself” (p. 100). Perhaps policymakers should increase efforts to incorporate teacher voices in teacher preparation programs and professional development offerings.

The role of professional development in supporting reform through increased science teacher self-efficacy was studied by van Driel, Beijard and Verloop (2000), who posited that one reason for lack of success in science education reform may be failure to take adult learning theory into account, specifically the top-down methodology with which much professional development is delivered, and failure to consider the teachers’ prior knowledge and beliefs that were constructed over the course of a teaching career and how these attitudes and beliefs shape the assimilation of new information. Like Marzano (2003), van Driel et al. addressed the disconnect between the intended
curriculum and the implemented curriculum, and acknowledged that in order for science reforms to be enacted, professional development must conform to the tenets of adult learning theory, or else be “doomed to fail…the implementation of reforms can be seen essentially as a matter of teacher learning” (p. 140).

**Summary**

Research regarding the state of STEM achievement and participation is examined in order to situate the research problem of quality and quantity of science education provided to primary-grade students as a long-term means of improving the state of the field. Teacher self-efficacy in science teaching methods and science content and adult learning theory as a means to improve both teacher content knowledge and pedagogical content knowledge are used as lenses.

**Definitions**

*Adult Learning Theory:* Malcolm Knowles’ (1962, 1972, 1974) pioneering work provided a process model of the differences between how children learn (pedagogy) and how adults learn (andragogy). Knowles (1972) focused on how life experiences shaped self-concept, increasing adults’ readiness to learn in order to problem solve, and asserted that effective adult learning is purposeful, acknowledges prior mastery, and provides significant autonomy (1974).

*California Standards Tests (CST):* Annual assessments administered in California from 1998 to 2012. CSTs for Sciences will be administered through 2017, followed by a field test of Next Generation Science Standards (NGSS) assessment in 2018. The operational test is scheduled to become active in 2019 (California Department of Education, 2014a). ELA and Mathematics CSTs were replaced by the California Assessment of Student Performance and Progress
Content knowledge: As described by Shulman (1986), this is the amount of knowledge a teacher possesses and how it is organized in his or her mind. Shulman posited that “the amount of subject matter content understanding of a teacher be at least equal to that of a lay colleague, the mere subject matter major” (p. 9), meaning that the content knowledge of teachers should be equal to a person holding a bachelor’s degree in a subject area.

Participation rate: For the purpose of this dissertation, the participation rate is defined as the percentage of students in high school and prospective teachers enrolled in STEM courses.

Pedagogical content knowledge: Shulman (1986) described this as knowledge of how to effectively structure and deliver curriculum for student learning. Shulman advocated for development of a “veritable armamentarium” of teaching strategies, understanding of scaffolding instruction for learning and the stages of student development (p. 9).

Persistence rate: For the purpose of this dissertation, the persistence rate is defined as the percentage of students who enroll in a STEM course and remain so until completion.

Professional Learning Communities (PLC): A collaborative learning network comprised of colleagues in a certain industry. For the purposes of this
dissertation, PLCs applied to a network of educators. The concept of PLCs is based on DuFour’s publications focused on school reform such as *Professional Learning Communities at Work: Best Practices for Enhancing Student Achievement* (DuFour & Eaker, 1998).

**Self-efficacy:** For the purpose of this dissertation, Bandura’s (1977) paper “Self-efficacy: Toward a Unifying Theory of Behavioral Change” provided a framework. Bandura posited that an individual’s efficacy expectations affected their behavior, which, in turn, affected their outcome expectations and actual outcomes.

**Science Teacher Efficacy Belief Instrument (STEBI):** A tool used to measure self-efficacy in teaching science. Two versions have been developed: STEBI-A for use with in-service teachers, and STEBI-B for use with pre-service teachers. The scale consists of 25 items rated on a 5-point Likert scale, and was developed by Riggs and Enochs (1990).

**STEM:** The fields of Science, Technology, Engineering and Math combined under one acronym as interconnected subjects. pSTEM is a subfield in which focus is placed on the physical sciences, such as Chemistry and Physics, and excludes the biological sciences.

**Teacher Education Program:** The sequence of courses completed by prospective teachers.
CHAPTER 2: REVIEW OF THE LITERATURE

Introduction

Public Policy and Science Assessment

Among the 34 OECD countries participating in PISA in 2012, U.S. students ranked average in reading, placing 17th, clearly below the OECD average in mathematics, placing at an estimated 27th place, and slightly below average in science, placing 20th (OECD, 2014b). Trend data from PISA appears to demonstrate no appreciable gains in achievement over the past 15 years despite the U.S. spending over double the amount per student than the Slovak Republic, the country with student performance most closely paralleling that of U.S. students (Hanushek, 2014; OECD, 2012; OECD, 2014a). The Slovak Republic spent an average of $53,000, less than half of the U.S. average of $115,000, which, when compared with per student spending among the OECD countries, places the U.S. fifth in per student spending, but with results that are at or below the OECD mean (OECD, 2014a).

The most recent *Trends in International Mathematics and Science Study* (TIMSS) (International Association for the Evaluation of Educational Achievement, 2011) results appeared to demonstrate no measurable difference in science scores of United States fourth graders between the years 1995 and 2011, despite a decade of standards-based instruction under the provisions of the No Child Left Behind Act of 2001 (NCLB). In the same time period, eighth grade students posted a minor increase in science proficiency. Under NCLB, student progress in general science is tested in grades 5 and 8, and high school students are tested in specific subject-matter competency, such as biology, chemistry, physics and integrated science (California Department of Education, 2015).
Achievement accountability models currently in effect in California do not place science education on equal footing with English/Language Arts and Mathematics, which may result in decreased instructional focus on the sciences as teachers strive to increase student achievement in the subjects for which they are held accountable through the teacher evaluation process (California Department of Education, 2013). At the elementary school level, student scores on the California Standards Tests (CST) were used to calculate a school’s score on the Academic Performance Index (API), a rating system used since 1999 to identify schools for inclusion in Program Improvement (PI). Through the PI process, schools deemed as underperforming based on the results of state assessments are at risk of losing Local Education Agency (LEA) autonomy to the California Department of Education (CDE) if improvement targets set by the CDE are not achieved within a specified time frame. While the CDE suspended use of the API model in 2014, a new state accountability system was developed and implemented during the 2015-2016 school year using data from the Smarter Balanced Assessment Consortium (SBAC) assessments (CDE, 2014a). However, as SBAC does not contain a discrete science component, CSTs for Science will continue to be administered to assess student achievement in these curricular areas through 2018 (CDE, 2014a).

To calculate the API for elementary schools under the NCLB model, student scores on the English/Language Arts (ELA) component of the CSTs comprised 56.5% of a school’s API; student scores on the Mathematics component comprised 37.6% of the API, and student performance levels on the Science component accounted for 5.9% of the score (CDE, 2013). In middle school API calculations, ELA scores accounted for 51.4% of API, Math for 34.3%, and Science for 7.1% (CDE, 2013). This data reveals that under the API system instituted by NCLB, high schools placed slightly more emphasis on student
performance in science disciplines than elementary and middle schools, as 22.9% of a high school’s API was determined by science scores. STEM education has been a political buzzword for most of the past decade, yet, for all of the publicity that it has received, there appears to be a disparity between the stated importance of the field and the policy enacted to support it, as ELA and Math tests are weighted significantly more than the Science tests (CDE, 2013).

Student achievement data from the CST-Science was analyzed for the years 2006 to 2012, and appears to show some gains in achievement on the standards-based assessments (CDE, 2006, 2007, 2008, 2009, 2010, 2011, 2012), with fifth grade scores improving from 32% of students scoring at the Advanced and Proficient levels in 2006 to 60% of students doing so in 2012. In the years between 2006 and 2012, eighth grade achievement increased from 38% of students scoring Advanced and Proficient in 2006 to 66% scoring at those levels in 2012. While these statistics demonstrate growth at the fifth and eighth grade levels, tenth grade Life Science scores demonstrated less improvement, with achievement ranging from a low of 35% of students scoring at the Advanced and Proficient levels in 2006 to a high of 53% in 2012. It is important to note that while these assessments may show some progress in science education, other assessment programs, such as PISA and TIMSS do not reflect such performance gains (CDE 2006; 2007; 2008; 2009; 2010, 2011, 2012; International Association for the Evaluation of Educational Achievement, 2011; OECD, 2013).

CST Sciences data for 2012 also revealed disparity in participation rates for the various sciences assessed through the program (CDE, 2012). According to the data published by the CDE, during 2012, roughly half a million students in each of grades 5, 8, and 10 participated in the CST assessments for general science, but the participation rate for subject examinations other than Biology decreased
significantly. Students in grades 9, 10 and 11 were eligible to enroll in a high school Biology course, and according to the report, ninth and tenth grade students representing 80% of high school Biology course enrollment in 2012. In that year, about a quarter million students in each of grades 9 and 10 enrolled in the course, in addition to roughly 100,000 students in eleventh grade for an end-of-course enrollment total of about 556,000 students. When achievement data for the course is examined, students in ninth grade had the highest level of achievement, with 60% of ninth grade students scoring at the Advanced or Proficient levels of the state assessment. Scores declined among tenth graders, with 43% scoring at the benchmark levels of Advanced and Proficient, and then rising among eleventh graders to 53%. High school Chemistry is open to the same grade levels as high school Biology, and about 275,000, or roughly half the number of students who take Biology, take Chemistry each year. Like the Biology course, achievement on CST-Chemistry is highest among ninth and tenth graders, with 52% and 51% scoring at the Advanced and Proficient levels, respectively. For the same course, 34% of 11th graders scored at the Advanced or Proficient levels. Compared to enrollment in Biology and Chemistry, the participation rate for high school Physics is very low, with only 80,872 total students taking the course in 2012, and 11th graders achieved the highest percentage of students scoring Advanced or Proficient, at 56%. From the data contained within this CDE report, it appears that policies enacted to increase the participation rate in the sciences within the state system are not producing an increase, particularly in the physical sciences.

**Education for the STEM Economy**

According to a report released by the Bureau of Labor Statistics, by the end of this decade, about 2.7 million new job opportunities in STEM fields are projected to be added to the national economy (Lacey & Wright, 2009). In the
Report to the President Prepare and Inspire: K-12 Education in Science, Technology, Engineering and Math (STEM) for America’s Future (President’s Council of Advisors on Science and Technology, 2010), the Council, or PCAST, expressed concern that students are increasingly choosing to earn college degrees in non-STEM fields over STEM fields, which may indicate weakness in STEM preparation pathways and result in the projected employment opportunities remaining vacant. The same concerns were addressed in Preparing the Next Generation of STEM Innovators: Identifying and Developing our Nation’s Human Capital (National Science Board, 2010) in which the Board emphasized the connection of STEM education to national prosperity and recommended that policies be implemented to address the issue. President Obama’s administration has created numerous initiatives and programs designed to address the perceived shortages of STEM prepared students and workers, and to improve the ability of workers to tap their human capital potential through increased educational opportunity. In the 2011 State of the Union address, Obama stated:

This is our generation's Sputnik moment. Two years ago, I said that we needed to reach a level of research and development we haven't seen since the height of the Space Race. In a few weeks, I will be sending a budget to Congress that helps us meet that goal. We'll invest in biomedical research, information technology, and especially clean energy technology – an investment that will strengthen our security, protect our planet, and create countless new jobs for our people…

Maintaining our leadership in research and technology is crucial to America's success. But if we want to win the future – if we want innovation to produce jobs in America and not overseas – then we also have to win the race to educate our kids.

Think about it. Over the next ten years, nearly half of all new jobs will require education that goes beyond a high school degree. And yet, as many as a quarter of our students aren't even finishing high school. The quality of our math and science education lags behind many other nations. America has fallen to 9th in the proportion of young people with a college degree. And so the question is whether all of us – as citizens, and as parents – are
willing to do what's necessary to give every child a chance to succeed (para. 25, 33, 34).

While President Obama’s commitment to support STEM education may be reflected in the policies enacted throughout his administration, remarks made in this speech appeared to express the administration’s serious economic concerns regarding declining STEM participation.

Policy recommendations included provisions for talent development through differentiated instruction and improved curricular coherence, opportunities for acceleration and increased rigor in scholarship, improved technology infrastructure, and increased STEM education requirements for general education teachers as means of solving the issues surrounding the perceived shortage of workers.

The 2012 PCAST report, Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics, forecasted a deficit of about one million STEM workers over the next decade and President Obama has repeatedly referred to the benefits of a STEM-strong economy. A plethora of STEM initiatives has emerged, both government-backed and public-private partnerships, like 100Kin10 and Complete College America, to assist students in their educational attainment (White House Office of the Press Secretary, 2015). Reports such as these published by PCAST are common, from Science- The Endless Frontier, penned by National Science Advisor Vannevar Bush in 1945, to the National Commission on Excellence in Education report A Nation at Risk in 1983, the report Shaping the Future: New Expectations for Undergraduate Education In Science, Mathematics, Engineering and Technology (National Science Foundation (NSF), 1996), and National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System (NSF, 2007). All of these
reports raised concerns regarding the ability of the U.S. education system to continue educating workers to the level required for the nation to retain its economic and political primacy, and resulted in reform to education policy designed to remedy causal factors perceived to contribute to systemic failures. Significant monies accompanied the reforms (Pea & Collins, 2008). These measures have taken many forms such as the creation of national committees on STEM education and appointment of STEM advisors, the development and adoption of STEM-specific curricula and pedagogical methodology, increases in graduation requirements, early childhood education programs, and emphasis on academic counseling and advising toward college- and career- readiness (Mattern, Radunzel & Westrick, 2015; NDEA, 1958; Sandall, 2003).

Ancillary Factors

Many researchers and government reports have addressed the wide array of contributing factors to the STEM crunch, from issues regarding race and gender equity (Miller & Wai, 2015; Riegle-Crumb, 2006; Riegle-Crumb, Farkas & Muller, 2006; Riegle-Crumb, Moore & Ramos-Wada, 2010; Riegle-Crumb, King, Grodsky & Muller, 2012) to the composition and qualifications of the workforce in general (Broughton, 2013; Winters, 2014; Wiswall, Stiefel & Boccardo, 2014), student persistence rates (ACT, 2014; Choi, Raley, Muller & Riegle-Crumb, 2008; Ehrenberg, 2010; Graham, Frederick, Byars-Winston, Hunter & Handelsman, 2013; National Center for Education Statistics, 2009; National Science Board, 2010; Ross et al., 2012; Zhang &Barnett, 2014), and the adequacy of resources and efficacy of curriculum (Epstein & Miller, 2011; Lederman & Lederman, 2014a, 2014b, 2014c, 2015; Sandall, 2003). Legislation such as the National Defense Education Act of 1958, the Elementary and Secondary Education Act of 1964, and its subsequent reauthorizations, and the No Child Left Behind Act of
2001 and it subsequent reauthorizations have sought to address these issues via increased opportunity, financial support, or curricular reform. When the combined efforts of the body of legislation and public and private initiatives to increase interest, participation and achievement in STEM fields is examined and contrasted with the actual outcomes, it appears that these programs have not produced the desired results.

The creation of the National Science Foundation by the National Science Foundation Act of 1950 was a significant event in the conduct of scientific investigation and education due to the resulting support of these fields under the law. President Harry Truman stated after signing the law

Throughout our history, scientists and scientific knowledge have contributed to our progress as a Nation. If you want to keep up that progress, we need to stimulate scientific discovery and research, and train more young men and women for our laboratories and research centers. To carry out these objectives, I have just signed the National Science Foundation Act of 1950. This act is of tremendous importance, because it will add to our knowledge in every branch of science. I am confident that it will help us to develop the best scientific brains in the Nation. It will enable the United States to maintain its leadership in scientific matters, and to exert a more vital force for peace. (Truman, 1950)

The purpose of the NSF as stated in the law was to support research and education in fields of science not pertaining to the practice or support of medicine, a mission with sufficient breadth and depth to facilitate research in diverse fields. In addition to investigations funding, the law provided for significant financial support for prospective STEM workers through grants, loans, scholarships and graduate fellowships. Each year, the NSF awards significant funds for research on a competitive merit basis. For Fiscal Year (FY) 2013, President Obama requested appropriations of over $7.3 billion for the agency as part of his Plan for Science and Innovation (NSF, 2012). When contrasted with the $33 million awarded to
approved grant proposals by the National Endowment for the Humanities (NEH) in 2013 (NEH, 2013), federal support of STEM fields dwarfs support of the humanities by over 200 times, yet in 2010, of the 5.5 million degrees awarded worldwide in STEM fields, only 500,000 were awarded in the U.S., with foreign nationals studying in the U.S. receiving a significant proportion of those degrees (Mattern et al., 2015). With so many resources being funneled into STEM education efforts, the question of why personnel shortages continue to exist is a current topic of study at the federal and institutional level (Chen & Weko, 2009; Graham et al., 2013; Thompson et al., 2007).

**Coherence Framework and Science Education**

The Public Education Leadership Project (PELP) at Harvard University was founded in 2003 with the mission of applying business management principles to education in order to support student achievement (President & Fellows of Harvard College, n.d.). PELP faculty members Childress, Elmore, Grossman and Johnson (2007) asserted in *Managing School Districts for High Performance: Cases in Public Education Leadership* that the most important work of a school occurs in classrooms, where teacher and students are interacting with content to form what the researchers called the “instructional core” (p. 3), a concept which relates to Tyack and Cuban’s (1995) assertion that what occurs in classrooms when the door closes becomes the de facto curriculum. This “core” described by Childress et al. is ensconced within the school, which has a distinct strategy for student achievement based on its structure, culture, systems, resources and stakeholders. The school is further situated within and interacts with a district that possesses its own distinct version of the same features of structure, culture, systems, resources and stakeholders. The district interacts with the external
environment to ensure educational equity and mastery learning for all students, while conforming to regulations, contracts, political developments and funding.

Viewing the issues surrounding science education through the lens of the coherence framework, it appears that student assessment strategies in place over much of the past two decades may have contributed to lowered priority on science education. By increasing emphasis on subjects included in accountability models and influencing the instructional core, school systems may have inadvertently contributed to the achievement gap in science education. Mensah (2010) conducted a case study of elementary science teachers in New York City to determine how education policy initiatives impacted elementary school science teachers. She contended that science education is a civil right that is being “ripped out of the curriculum in terms of time, access and quality” (Mensah, 2010, p. 981), and that the marginalization of elementary science education impacts students’ future learning, as elementary science education provides the foundational knowledge and skills needed to perform in secondary school science classes. Mensah further claimed that elementary science education suffers from the lack of expertise in CK and PCK of elementary school teachers, and in an era of accountability models, “science becomes the subject relegated as least important in the overall school curriculum” (p. 979), and advocated for increased professional development opportunities for elementary school science teachers. According to Mensah’s findings, current education policy may be a mitigating factor in the STEM crunch, which were supported by Carrier, Tugurian and Thomson (2013).

In their mixed-methods study of elementary science education, Carrier et al. (2013) asserted that “high-stakes testing in reading and mathematics have diminished the time spent in science, as well as limiting effective teaching
practices” (p. 2061). In this study, the researchers developed a science curriculum and tested its efficacy. Quantitative data were collected through use of a pre- and post-test format in which a 48 item instrument was developed (alpha = .72) and administered to 49 students from a Title 1 rural/suburban school in North Carolina with significant populations of Latino (33%) and African-American (27%) students, and socioeconomically disadvantaged students (54%); qualitative data were derived from interviews with two teachers of science and the principal, in addition to field notes of classroom observations. Paired t-tests indicated that all students demonstrated growth in their overall science content knowledge over the course of the year \( t = 7.81, p < .001 \), as the pre-test scores \( M = 48.59, SD = 12.7 \) were significantly lower than the post-test scores \( M = 64.05, SD = 16.5 \). Analysis of qualitative data appeared to show that resource constraints and standardized testing were perceived as the major inhibitors to science education. An additional significance of this study is that it may demonstrate the malleability of student interest in science, as the researchers developed the curriculum with information regarding the amount of time that children spend outdoors and in front of screens in mind. The end product contained a significant environmental component that required students to interact with the environment while learning.

Alexander, Johnson and Kelley (2012) conducted a 3-year longitudinal study from 1999 to 2003 on the relationship between parental reports of children’s science interests and the informal opportunities for learning about science afforded to 192 children aged 4 to 7. Informal science learning opportunities were categorized as the acquisition of toys, books, educational trips, and exposure to electronic media. During the study, parents of 4- and 5-year-olds completed a 14 item questionnaire regarding the family activities that involved science. When the children were six, parents were asked to complete a survey that asked for more
detailed information regarding science education activities, such as television shows watched and involvement in community-based science activities. The results were first analyzed using an ANOVA with time as the within factor \((F(2, 398) = 21.34, \ p < .001)\) and gender \((F(1, 199) = 30.41, \ p < .001)\) as the between factor, with a significant interaction between the two \((F(2, 398) = 9.54, \ p = .001)\). The researchers then used an ANCOVA with age, gender, and family activities as co-variants. Family activities was significant \((F(1, 189) = 37.53, \ p < .001)\), as was gender \((F(1, 189) = 7.51, \ p < .001)\).

Of the strands of informal science learning opportunities for four-year olds (modeling, computer, animals, science, gardening, paleontology and electronics), Alexander et al. (2012) found that girls were afforded more learning opportunities than boys in only two areas – animals (girls \(M = .88, \ SD = 1.02\); boys \(M = .73, \ SD = 1.05\)) and gardening (girls \(M = 1.05, \ SD = .89\); boys \(M = .97, \ SD = .87\)). Among informal science learning opportunities for six-year olds, boys \((M = 5.72, \ SD = 7.75)\) were more likely to have been exposed to constructivist-oriented activities than girls \((M = 4.98, \ SD = 9.02)\). Girls were more likely to be afforded passive opportunities for learning science such as reading a book (girls \(M = 2.00, \ SD = 1.26\); boys \(M = 1.95, \ SD = 1.22\)) or watching a tv program on science (girls \(M = 2.56, \ SD = 1.02\); boys \(M = 2.12, \ SD = 1.20\)). The study also appeared to reveal a gendered disparity in science interest among the parents. Ninety-three percent of the respondents were mothers. In response to the question “How interested are you in science?” posed to parents rated on a 5-point Likert scale with 1 being not very interested, and 5 being very interested, males expressed much more interest \((M = 4.09, \ SD = .97)\) than females \((M = 1.07, \ SD = 1.00)\).

The research appeared to indicate that boys were afforded more science education opportunities than girls, particularly in the physical sciences, and to be
more actively engaged in learning about science. Informal science education opportunities for girls leaned toward the biological sciences. Although opportunities did equalize over time, by age 6, the study seemed to indicate that boys were more interested in science than girls overall. Data from the study regarding parent interest in science appeared to mirror this finding. Alexander et al. (2011) stated that their data did not demonstrate a direct effect of early informal science learning opportunities for this age demographic in subsequent science-related interests, but they did report that as the students from this study entered first grade, parents reported a decline in science-related activities, particularly among boys. This decline may have been the result of less free time to engage in science-related activities, or alignment of interests with peers. No definitive answer was supplied by this study.

A perceived decline in science interest among students in grades 5–11 was examined by Potvin and Hasni (2014) through a 7-year longitudinal study of 2,628 students in Montreal, Canada. Efforts were made during recruitment at schools to ensure that the students selected for the study were “typical or representative” (Potvin & Hasni, 2014, p. 790). A secondary component of the study was a meta-analysis of 21 studies across several countries involving 19,510 students regarding student interest in science. Of the 21 studies analyzed, only two appeared to find an increase in student interest in science, one in Scotland (Reid & Skryabina, as cited in Potvin & Hasni, 2014), and the other in Australia (Hassan, 2008); interestingly both appeared to reveal an increase science interest in the course taken in Grade 11, which focused on life science. Two versions of a questionnaire, one long and consisting of 139-item questionnaire composed of 126 Likert-style questions mostly scored on a 6-point scale, but some items with a 4-point scale, 8 open-ended questions, and 5 questions regarding social contexts was
administered to students whose last names began with A to J; a shorter version was administered to students whose last names began with K to Z as a safeguard against the influence of survey fatigue on data collection. A linear regression analysis was used. To study the main research question regarding “interest in school science and technology” (Potvin & Hasni, 2014, p. 791) data were collected through student responses to five items on the questionnaire (alpha = .89, N = 1,241, p < .001). Data regarding sub-contexts as “difficulty of school science and technology” (Potvin & Hasni, 2014, p. 791) were collected from six items on the questionnaire (alpha = .83, N = 939, p = .017). Data regarding “attraction to S&T studies and careers” (Potvin & Hasni, 2014, p. 791) were collected from six items (alpha = .91, N = 2,381, p = .005). The data collected in this study appeared to support the assertion that although students understood that achievement in science and technology was valuable, over time, their interest in the fields declined “the equivalent of one entire point on our 6-level Likert-type scales. Therefore, as they grow older, children appear less and less interested in S&T” (Potvin & Hasni, 2014, p. 795). Potvin and Hasni (2014) posited that pedagogy to increase student interest in school science and technology is “not a futile affair. If fact, it can contribute to better learning, which in turn contributes to society…We believe it is possible to increase interest in S&T without letting the challenge it represents lose its lustre” (p. 798). The challenges, though, may be more disposed toward resources and teacher competency.

In What Works in Schools: Translating Research into Action, Marzano (2003) explored the disparity between what he termed the “intended,” “implemented” and “attained” curriculum (p. 23). The intended curriculum setting forth what students should know and do is expressed in curriculum frameworks produced by states or local education agencies. The implemented curriculum
consists of what is taught in the classroom, and the attained curriculum is the learning that students demonstrate via assessment. The disparity between the three curricular prongs has been frequently documented in the results of OECD, TIMSS and National Assessment of Education Progress (NAEP) assessments, as U.S. student performance seems to perpetually lag behind that of other industrialized nations. Marzano (2003) and DuFour and Fullan (2013) suggested that this discrepancy, the lack of what Marzano called a “coherent implemented curriculum” (p. 24) may be the result of a lack of clarity and coherence regarding what school leaders think occurs in classrooms and what actually happens, and presents a leadership challenge that should be addressed to ensure that all students have access to the full curriculum. However, school leadership should not bear the brunt of blame for the equity issues created by the legislative accountability models currently in effect. When the confines of standards-based education and a 180-day average school year are taken into consideration, assessment policies that place greater emphasis on some subjects at the expense of others that are not assessed via state tests may contribute to such omission from the curriculum in order to gain instructional time for the subjects for which teachers, administrators and school are held accountable.

Historian of education, Diane Ravitch, has been highly critical of the curricular movement to focus only on the subjects for which students take state assessments, and asserted that such action presented an equity issue, as students in low-performing schools are more likely to be impoverished and because they belong to a lower socio-economic class, may be denied access to the full curriculum, which violates their right to equal protection under the Fourteenth Amendment (Ravitch, 2010). In The Death and Life of the Great American School System: How Testing and Choice Are Undermining Education, she cited a
2007 study by the Center on Education Policy in which a representative sample of school districts reported that they had increased instructional time in the accountability subjects of reading and mathematics by 62%, while instruction in the non-accountability model subjects of science, social studies and the arts had decreased by 44% (Ravitch, 2010, p. 108). DuFour and Fullan (2013) addressed this issue of disparity between the intended and implemented curricula, and called for teacher-leaders to plan and deliver a guaranteed curriculum. However, they assert that such a thing can only occur when “those who are called upon to implement the curriculum – the teachers themselves – are the ones making the guarantee to the students and their colleagues” (DuFour & Fullan, 2013, p. 55). They advocate for the use of professional learning communities (PLCs) to address disparities between the intended and implemented curricula; however, effective PLCs balance on a fulcrum of teacher self-efficacy and priorities established by school leadership. If teachers do not view themselves as being sufficiently educated in science content or proficient in pedagogical content knowledge for the sciences, their ability to effectively deliver an enacted science curriculum to students may be reduced.

The California Standards for the Teaching Profession (CSTP) provide the framework for teacher evaluation and contain six meta-standards with supporting sub-standards (California Commission on Teacher Credentialing, 2009). The meta-standards regarding student engagement in learning (Standard 1), understanding and organizing subject matter for student learning (Standard 3), planning instruction and designing learning experiences for all students (Standard 4), and developing as a professional educator (Standard 6) strongly relate to providing access to the full curriculum for all students. If school leadership from the state level down to site level does not require that students receive such access,
instead, focusing on the subjects that are assessed by high-stakes testing, the STEM crunch will most likely intensify, complicating an already complex equity, human capital development and economic problem.

**Science Educator Pipeline**

In *STEM Educator Pipeline: Doing the Math on Recruiting Math and Science Teachers* (American College Testing [ACT], 2013a), the educational readiness of almost 1.8 million high school students was examined. Based on student responses to possible career paths, the population data gathered by the ACT were disaggregated into several subcategories based on career interests and college readiness. Of these subcategories, the population of students who were interested in pursuing a career in STEM and were academically prepared to do so, and the population of students who planned to pursue a career as a STEM educator and were academically prepared to do so were of particular interest. Nationally, about 25% of students who take the ACT each year meet college readiness goals in all four of the subjects tested (English, Reading, Mathematics and Science). When the data were disaggregated by intended major, Chemical Engineering (65%), Aerospace/Aeronautical Engineering (56%) and Biochemistry/Biophysics (56%) have the highest rates of students meeting all four college readiness goals (ACT, 2013a).

The achievement of students interested in careers in the five fastest-growing career fields - education, management, computer and information technology, community services and marketing/sales was examined in *The Condition of College and Career Readiness 2013* (ACT, 2013b). When scores in the four subject areas tested by the ACT for these career fields were compared, student achievement on the Science test was the lowest, with 31% of students in this group meeting the benchmark score. According to *The Condition of College
and Career Readiness 2015 (ACT, 2015), of the students interested in Elementary Education as a career field, 32% passed the Science benchmark test, and 21% met all four college readiness goals, representing a significant gap in the overall college readiness of prospective educators as compared to other career fields, and STEM fields in particular. Lack of achievement in the sciences during preparation for college and subsequent course taking while enrolled in post-secondary education does not bode well for classroom teaching practice.

Of the roughly 75,000 students who expressed some interest on the 2013 ACT in pursuing a career in education, 3,146, or .25%, expressed the desire to become a math teacher, while 731, or .06% of students, stated that they may pursue a career as a science educator (ACT, 2013a). When the 2013 data from the California STEM Report (ACT, 2013c) is examined, of the 107,243 students who took the ACT, 49.95% have no interest in pursuing a career in STEM. Of the other half of students who were interested in pursuing a STEM career, about 10% of them expressed specific interest in either Nursing or Medicine (pre-med) as a college major, which represents a significant number of students interested in only two of the 103 potential career fields. In the Condition of College and Career Readiness 2015 – National (ACT, 2015), three of the top five career fields chosen by students who took the ACT were Nursing, Pre-Med and Biology, representing 183,117 students who took the test. Business Administration and Mechanical Engineering rounded out the top five potential career fields. Only about 18,000 students responded that they planned to become elementary school teachers, and of the 107,243 students in California who took the ACT in 2013, only 14 had an expressed and measured interest in becoming science teachers, and 30 had an expressed and measured interest in becoming math teachers (ACT 2013c). The
goal of the 10,000in10 initiative to prepare 10,000 new STEM teachers by the end of this decade appears to be unattainable, particularly in light of these statistics.

The *STEM Educator Pipeline* report (ACT, 2013a) examined the feasibility of reaching this goal, and recommended, as many reports have done, intensification of recruiting efforts targeted at STEM-prepared students who did not express interest in becoming STEM educators, but the report acknowledged that too few students are both prepared and interested in a career in education to have a positive impact on the potential teacher workforce shortage. Additionally, the report recommends that STEM educator salaries be more aligned with industry salaries and the use of bonus pay structures to incentivize workers who are prepared and interested in STEM fields to consider a career in education over private industry. The final recommendation of the report in addressing solutions to the STEM human capital crisis is one that is directly actionable by primary grade teachers – high-quality science instruction in the early grades in order to prepare students for continued study. However, in order for teachers in the primary grades to have an impact on the STEM crisis, policies that increase science teacher self-efficacy through teacher preparation and school accountability models that place more emphasis on science content and pedagogy should be implemented.

**Child Development and Science Education**

The natural curiosity of young children has been noted for millennia by philosophers and scientists from Aristotle to Rousseau to Freud, and provides fertile ground for the cultivation of a love of learning (Beatty, 1995; Shields, 2012; Swim & Watson, 2008). Educators in primary grades have the ability to make significant contribution to increased participation in STEM fields by placing more emphasis on science education during these formative years (National Research
Council [NRC], 2007, 2012; National Science Teachers Association (NSTA), 2014). The NSTA posited that that educators often underestimate the ability of young children to construct meaning about core scientific concepts, and therefore, limit student experiences with science (NSTA, 2014), a position that was supported by the Governing Board of the National Association for the Education of the Young Child (NAEYC) in a joint statement with the NSTA (NAEYC, n.d.). As the consequences of such limitations on science education appear later in elementary school as decreased interest or an attitude of not being “good” at science, the NAEYC advocated for increased science content for pre-school-aged children, and called upon teachers to increase student engagement with science, and upon LEAs to increase professional development (PD) activities for all teachers of science (NSTA, 2014).

In *Science of Education and the Psychology of the Young Child*, Piaget (1970) examined the cultural role of education and the processes by which education functionaries have sought to accomplish societal goals for education. He proposed that “if the aim of intellectual training is to form the intelligence rather than stock the memory, and to produce intellectual explorers rather than mere erudition, then traditional education is manifestly guilty of a grave deficiency” (Piaget, 1970, p. 51). Piaget specifically addressed deficiencies in science education pedagogy by critiquing the non-constructivist methods commonly used to deliver content, and stated that such instructional methods were about as effective as sitting “in rows on a wharf and learn[ing] to swim by watching grown-up swimmers in the water” (p. 51). He attributed pedagogical deficiencies to the views teachers possessed regarding their own self-efficacy. These views, according to Piaget, affected societal perceptions of teachers as “the mere transmitter of a kind of knowledge that is within everyone’s grasp...it is
considered that a good teacher is providing what is expected of him when he is in possession of a general elementary education” (p. 11). Following Piaget’s reasoning, if issues centered on teacher self-efficacy in teaching science were resolved in pre-service and teacher education programs, the quality of the implemented curriculum would improve, resulting in increased student achievement.

Piaget (1970) asserted that “pedagogy is a science comparable with other sciences, and even a very difficult one, given the complexity of the factors involved” (p. 14). He called on teachers to become more reflective in their teaching practice, to ensure that access to the full curriculum – to all the “branches of education…branches of reasoning…and above all, branches of experimentation” (p. 12) be provided, while taking into consideration the stages of developmental readiness to learn. He asserted that primary school teachers are intellectually isolated from research and development in both pedagogy and subject content by programs that “lack entirely any direct link with university research” (p. 14) and fail to develop deep understanding of how children learn during the preoperational and concrete operational periods of development. Piaget appeared to advocate that knowledge of child development should guide the preparation and practice of elementary school teachers, as all teachers require understanding of how children acquire and assimilate knowledge in order to plan and conduct lessons. However, for primary teachers, this may be especially important, as the transition from the pre-operational stage of child development to the concrete operational stage is vital for subsequent learning experiences in the formal operational stage (Henry, 1978; Salkind, 2004).

Support for exposing students to constructivist-based science lessons in the pre-operational stage may be found in a study conducted by Henry (1978)
involving 6-year-olds in Victoria, Australia. The study consisted of two groups – the control group, which received the regular instructional program proscribed by the territorial education ministry, and the treatment group, which, over the course of 15 weeks, participated twice a week in a 1-hour science-based sorting and classifying lesson. The results of this study in discrimination and classification suggested that students who participated in science lessons that required students to use sensory or observational data to compare/contrast and sort by attribute “exhibited a higher level of cognitive development for all tasks” (Henry, 1978, p. 151), even when covariates such as gender and intelligence as measured by the pretest were considered. When these findings, as well as Piaget’s classification of the stages of child development, are put into conversation with Bruner’s work in the “spiral curriculum” in which age-appropriate lessons provide an increasingly complex foundation as concepts are revisited and layers of content are added (Gibbs, 2014), they interact to provide a solid foundation to support the proposition that teachers of primary students have been in a unique position to take action to address the STEM crisis.

The persistence of a shortage of qualified STEM workers may be attributed to ineffective policies regarding establishment of educational priorities in the early grades or to the systemic neglect of science education in the primary grades. When viewed through a long-term lens, these factors may have significant and far-reaching negative effects in on the economy, culture and environment. Instructional leadership may lie at the crux of the issue, and solutions to address deficiencies in may be found in establishment of policies to remedy the disparities between the enacted and implemented curricula. Doing so may guarantee that all students have access to equitable learning opportunities, and teacher-leaders should strive to ensure that all students have access to the full curriculum. Review
of student achievement data may provide information regarding the rigor and quality of academic preparation in sciences present in area school districts. This will, in turn, serve to inform professional development in these school districts and assist teacher education faculty in developing highly qualified teachers of science through the multiple-subject credential program to serve school districts.

**Self-Efficacy and Teacher Preparation**

**Self-Efficacy**

In 1976, researchers at the RAND Corporation, a global non-profit research organization, studied the concept of self-efficacy (Armor et al., 1976). Through teacher responses to items added to a survey they developed regarding reading instruction in Los Angeles schools, teacher self-efficacy as a discrete subfield within the greater context of self-efficacy as defined by Bandura (1977) was established (Tschannen-Moran, Woolfolk-Hoy & Hoy, 1998). Teacher self-efficacy was defined as the belief that student achievement was directly attributable to the teacher’s ability to use appropriate pedagogical methods to deliver content which then had a positive impact on student learning. The two items that were added and yielded such insight into the internal processes of teachers focused on the effects of learning environments external to school and motivation factors among both teachers and students.

The first item, RAND Item 1: “When it comes right down to it, a teacher really can’t do much because most of a student’s motivation and performance depends on his or her home environment” (Armor et al., 1976, p. 206), was intended to measure how teachers felt about their ability to influence student learning in spite of factors outside of teachers’ control that exerted negative influences. The second question, RAND Item 2: “If I really try hard, I can get
through to even the most difficult or unmotivated students” (Armor et al., 1976, p. 206), gathered data regarding teacher confidence in his or her ability to create and maintain an effective and engaging learning environment. When data from the scores of these two items were added together, the construct of teacher efficacy emerged – that intentional, purposeful action taken by educators could positively impact student learning and motivation (Tschannan-Moran et al., 1998).

Self-efficacy was described in Bandura’s (1977) seminal work as the belief that intentional action taken toward a specific goal can lead to the desired outcome. Building on the RAND survey data (1976) and Bandura’s (1977) work, Gibson and Dembo (1984) developed a self-efficacy survey, and postulated that two social-cognitive domains inform teacher self-efficacy: personal teaching efficacy (alpha = .75) and general teaching efficacy (alpha = .79). By analyzing data from 208 elementary school teachers on RAND Items 1 and 2, the researchers posited that teacher self-efficacy accounted for 10% to 18% of the variance between teachers in student outcomes. Further tests of the survey items in a shorter form appeared to support Gibson and Dembo’s (1984) findings (Hoy & Woolfolk, 1990; Woolfolk & Hoy, 1993).

Byars-Winston and Fouad (2008) examined the effects of formative personal experiences, such as school culture and socioeconomic status, family dynamics, and peer relationships as they relate to STEM content knowledge self-efficacy and career choice using subject matter scales developed by Smith and Fouad (1999) (alpha = .85). Two hundred twenty-seven undergraduates at two large universities in the Midwest United States participated in the study, and all subjects had taken between 3.5 and 3.9 years of high school math and science courses. Researchers performed a 2 x 2 MANOVA (gender x campus) on the variables, and while campus did not appear to make a difference, significant
differences by gender were reported in four of nine areas; males reported higher levels of math and science self-efficacy, outcome expectancies, and parental involvement, and females perceived more career barriers to STEM fields than males ($F(9, 194) = 4.25, p < .001$). Of the factors examined, parental involvement, coping self-efficacy and outcome expectation had the greatest effects on achievement in math and science. Negative experiences with content and social cognitive factors during formative years may steer students away from possible careers paths by creating lowered perceptions of self-efficacy and outcome expectations. Byars-Winston and Fouad’s (2008) work is strongly related to that of Riegle-Crumb et al. (2006), Lederman and Lederman (2014a), and Ravitch (2010) regarding gender and socioeconomic equity issues in teaching and resources, and multiple studies have revealed a connection between low achievement in science and math and long-term economic outcomes. Review of occupations with the highest levels of compensation reveals that all 10 of the jobs earning the highest salaries within 3 years of college graduation are STEM related, such as chemical and electrical engineering, computer engineering and software design, and the math-intensive field of finance (Dill, 2015). STEM self-efficacy may be directly related to career choices and lifetime earning potential.

Riggs and Enochs (1990) developed a tool to study elementary teachers’ science teaching self-efficacy beliefs in response to a 1983 report by the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology in which the Commission emphasized the importance of early science education experiences in potential achievement. Building on the two domains of teacher self-efficacy identified by Gibson and Dembo (1984), Riggs and Enochs (1990) focused on science education to develop the Science Teacher Efficacy Belief Instrument (STEBI). The researchers perceived an absence of literature
regarding the role of belief in self-efficacy in shaping elementary teachers’ attitudes toward teaching science, which in turn, led to behaviors regarding their science teaching practices. The STEBI consists of two forms – STEBI-A for use with in-service teachers, and STEBI-B for preservice teachers, and measures teacher self-efficacy and outcome expectations. Both forms have been used to explore teacher behavior regarding science education, and the authors assert that such exploration “can facilitate the development of strategies which may assist in teacher preparation and teacher in-service designed to improve elementary science teaching” (Riggs & Enochs, 1990, p. 633). The researchers reported that teachers with higher levels of self-efficacy for teaching science spent more time actually teaching science as compared to teachers with lower levels of science teaching self-efficacy. Not only did the level of science teaching self-efficacy affect the amount of time teaching science, it also influenced the activities to which students were exposed during science lessons, which, in turn, affected student learning outcomes (Enochs, Scharmann, & Riggs, 1995).

When this research is viewed with the work of Shulman (1986) it appears that effective teachers must possess two types of knowledge: subject matter expertise (content knowledge, or CK) and the body of competencies that inform best practices in transmitting disciplinary knowledge to students (pedagogical content knowledge, or PCK). Shulman (1986) proposed that knowledge across the discrete domains of content and methodology, student development, and how school systems function was critical to teaching efficacy. Two decades later, Bandura (1997) addressed the issue of teacher efficacy, and posited that teacher self-efficacy varied according to the task teachers were required to perform. He posited that teacher tasks fit into one of four categories: mastery experiences, physiological and emotional states, vicarious experiences, and social persuasion.
Mastery experiences were defined as success in accomplishment of a task.
Physiological and emotional states referred to feelings of excitement or anxiety;
vicarious experiences were described as the level to which one identifies with an
observed subject or model. Social persuasion consisted of feedback regarding
Teaching performance. Of these sources, Bandura (1997) asserted that mastery
experiences were the most effective in increasing teacher self-efficacy, followed
by vicarious experiences. Teacher education programs appear to integrate all four
categories through exposure to content, apprentice teaching and evaluation to
some extent.

**Science Teacher Self-Efficacy**

Since publication of Riggs and Enochs’ (1990) work in science teaching
self-efficacy, many researchers have examined the development of science
teaching self-efficacy among preservice teachers. Buss (2009) studied the efficacy
beliefs of 325 prospective teachers who had completed two general education
Science courses during their undergraduate preparation. An efficacy beliefs
instrument consisting of 15 items, three from each content area of reading, math,
science, classroom management and general instruction on a 6-point Likert scale,
was used. Cronbach’s alpha reliability coefficients for efficacy in teaching (EFT)
each of the content areas showed high reliability of the instrument: EFT science
(alpha = .82); EFT math (alpha = .87); EFT reading (alpha = .71); EFT classroom
management (alpha = .84) and general classroom instruction (alpha = .81). A
repeated measure ANOVA was performed and revealed differences in self-
efficacy among the different content areas ($F(4, 1296) = 64.65, p < .001$).
Preservice teachers participating in the study had higher EFT in reading ($M = 4.98$),
classroom management ($M = 5.17$) and general instruction ($M = 5.27$) than
they did for math ($M = 4.82$), and science ($M = 4.64$) was the lowest of the five content areas. Buss (2009) asserted that

Given that efficacy beliefs develop early and are somewhat resistant to change, the implications for teacher preparation are quite compelling because preservice teachers’ efficacy is more malleable since they have fewer mastery experiences…it is clear that differentiated instruction is warranted for students in teacher preparation programs. Specifically, individual students may benefit from learning additional content material…especially in the areas of science and mathematics. (p. 296)

In an effort to “re-examine the factor analysis structure supporting the original two scales represented in the STEBI-B” (p. 385), Bleicher (2004) administered the survey to 290 students enrolled in an elementary science methods course at a Florida university. Using an independent $t$-test for data with two groups (males and females), or ANOVA if more than two groups were present (age, ethnicity), Bleicher reinforced the separate constructs of PSTE and STOE. Males ($M = 50.78, SD = 7.50$) were found to have significantly higher PSTE than females ($M = 45.29, SD = 6.80, t(-4.24), p < .01$). The number of science course taken appeared to have an impact on PSTE, as students who had taken zero to three science courses had significantly lower PSTE than students who had taken four to seven courses ($F(2, 287) = 12.96, p = .01$). The quality of K-12 science experiences appeared to have an impact of PSTE ($r = .305$), as student with positive experiences had higher science self-efficacy ($M = 48.35, SD = 6.68$) than students who had negative experiences in K-12 settings, ($M = 44. 01, SD = 6.74$) ($t(5.11), p < .01$). The means and standard deviations of all 23 STEBI-B items in Bleicher’s study closely paralleled the data from Riggs and Enochs’ (1990) study. In response to research findings that elementary teachers spend less time teaching science than any other subject, and that the most common science activity was reading the textbook, Christol and Adams (2006) administered pre- and post-
course STEBI-B to 55 students enrolled in *Science in the Elementary School* at Oklahoma’s Northeastern State University during the Spring 2005 semester. Through the use of an independent, two-tailed *t*-test, Christol and Adams found a significant difference between students’ pre-course PSTE (*M* = 46.76, *SD* = 6.07) and the post-course PSTE (*M* = 49.92, *SD* = 6.06, *t* = 2.70, *p* < .01). Results for STOE, however, did not show a significant difference between pre-course (*M* = 35.11, *SD* = 0.571) and post-course (*M* = 35.98, *SD* = 0.515).

Giallousi et al. (2014) investigated the science teaching self-efficacy beliefs of freshman students enrolled in a constructivist-oriented early childhood education science course at the University of Athens in Greece during the 2010–2011 academic year. The researchers chose to focus on freshmen because they hypothesized that the science teaching and learning experiences of this population was derived from their secondary school experiences, and that many students enrolled in the course were afraid of or disliked science and “believe[d] they don’t know or can’t learn anything about it” (p. 339). A modified STEBI-B was administered pre-course (alpha = .81) and post-course (alpha = .83), and a one way ANOVA was performed regarding self-efficacy and outcomes beliefs. Students were placed in a group dependent on whether their science teaching efficacy beliefs improved (Enhancement beliefs) or worsened (Worsening beliefs) after completing the class, followed by personal interviews. The Enhancement beliefs group (pre-course *M* = 2.75; post-course *M* = 3.87) had higher ratings efficacy ratings in vicarious experiences (Bandura, 1997) regarding modeling of pedagogical methods than the Worsening beliefs group (pre-course *M* = 4.29; post-course *M* = 2.29), and a more positive attitude (pre-course *M* = 2.60; post-course *M* = 3.70) of the class than the Worsening beliefs group (pre-source *M* = 4.00; post-course *M* = 2.63). It appeared that many students in the Worsening
beliefs group struggled with the constructivist-oriented approach used in the class, with the instructor-as-facilitator rather than transmitter, and “maintained their belief about the nature of science teaching – as a transmission of knowledge – and the related evaluation of its results” (Giallousi, Tselfes, & Gialamas, 2014, p. 352). These findings appear to support the assertion that personal self-efficacy in learning is related to achievement.

Baldwin (2014) embarked on a study of 50 prospective elementary school teachers in response to the growing body of scholarship regarding “the concern that many elementary teachers hold negative attitudes toward science, lack confidence to effectively teach science, and do not feel they have the necessary expertise to teach science” (p. 206). By administering the STEBI-B during the first and last class sessions of an introductory geology course with separate laboratory sections geared toward elementary education majors, Baldwin found that the participants’ personal science teaching efficacy (PSTE) increased, but that their science teaching outcome expectancy (STOE) did not. The STEBI-B consisted of 23 items on a 5-point Likert scale with items designed to measure PSTE (alpha = .90) and STOE (alpha = .76) (Riggs & Enochs, 1990). Paired t-tests were used to determine if participants’ PSTE and STOE means changed from the beginning of the course to the end. PSTE changed significantly from the pretest ($M = 47.28$, $SD = 5.36$) to the posttest ($M = 51.10$, $SD = 5.04$, $t(49) = 4.79$, $p < .001$). STOE did not show a significant effect from the pretest ($M = 34.82$, $SD = 3.76$) and the posttest ($M = 35.00$, $SD = 4.16$, $t(49) = .347$, $p = .730$). These findings appear to support the development of science content courses specifically for education majors in order to increase teaching self-efficacy.

The state of science education specifically in California was the subject of Gomez-Zwiep’s (2008) study of 30 teachers of grades 3, 4, or 5 representing 12
schools across seven school districts with populations of socio-economically disadvantaged and English learner populations. All participants were fully-credentialed teachers and had at least one year of teaching experience. Although two participants had 28 years of experience, and one had 35 years of experience; the mean years of experience appeared to be fewer than 10. Using semi-structured interviews, Gomez-Zwiep (2008) gathered data regarding the content and sources of science misconceptions possessed by students and the actions that teachers took in response to these misconceptions. In the study a “misconception” was defined as a “belief that contradicts accepted scientific theory” (p. 441), and most teachers interviewed had some understanding of the term. Participants “expressed concern over the developmental level of their students and the content they were required to teach at that grade level” (p. 443), frequently abstract concepts for which students had no reliable pre-existing schema. Rather, teachers asserted that students’ prior knowledge was a construct of erroneous information from external sources such as television, religious education, and adults with limited formal education. In response to erroneous constructs created by students, Gomez-Zwiep advocated for guided learning opportunities in which students learn to handle materials and make observations, pose questions regarding their observations for discussion and clarification by the teacher, and apply their learning to new situations as assessment. Although the teachers in the study supported hands-on learning, most used traditional teaching methods, perhaps exposing weakness in both content knowledge (CK) and pedagogical content knowledge (PCK) by the absence of constructivist-based classroom science activities.

Other researchers have examined alternate routes to increasing science teaching self-efficacy. Lederman and Lederman (2015) described PCK as the “construct to bring disciplinary knowledge back into the equation of what it takes
to become an effective teacher” (p. 4). Science teacher self-efficacy is significant as a measure of both science achievement in preparation for a career in teaching, and as a measure of confidence in the ability to transmit accumulated knowledge to students in an effective manner. Accumulation of science content knowledge should begin as soon as children are ready for such learning, and lays a foundation for subsequent learning in accordance with Bruner’s (1960) work regarding a spiral curriculum, in which more rigorous subject matter is presented as the subject is revisited with progressive turns of the curriculum spiral. Pedagogical content knowledge is accumulated throughout a prospective teacher’s career through application of pedagogy methods acquired while a student, which are then mimicked in one’s own practice, and also by explicit instruction and demonstration teaching in teacher education programs (Appleton & Kindt, 2002). Data drawn from their qualitative study of nine elementary teachers of science in Australia appear to support the conclusion that elementary teachers of science “have had limited success in their own science learning…[with] consequent effects on their self-efficacy in science and therefore their image of self as a teacher of science” (Appleton & Kindt, 2002, p. 45). Factors suggested as contributors to the low rates of science self-efficacy were overall lack of science knowledge, poor preparation during TEPs, and lack of resources. The teachers participating in the study were likely to deliver lessons “having predictable outcomes, and were drawn from the teachers’ own experience or that of colleagues” (Appleton & Kindt, 2002, p. 49). Further, the lessons taught were “determined by personal choice, with little influence from the proscribed syllabus, suggested content provided in sourcebooks, or school policy…Common examples included ‘researching’ in books, writing reports, and class ‘discussions’” (p. 50). These observations appear to echo the suggestion that changes to the pre-service
education of prospective teachers be made in order to strengthen science CK, and thus, science PCK.

Bartos, Lederman, and Lederman (2014) investigated the subject matter knowledge structures (SMKS), of four high school Physics teachers in order to determine the differences between the way that experts and novices created connections between subjects and sequenced instruction for student learning. Three of the teachers had 6 years or fewer of Physics teaching experience; one had 23 years of experience teaching Physics. By mapping the inferred subject matter knowledge structure of each participant, the researchers appeared to demonstrate that development of SMKS is a result of reflection on teaching practice, and suggested that teachers who possessed “more coherent and integrated SMKS tend to more closely reflect these structures throughout their classroom, and are more successful in capitalizing upon unforeseen opportunities to address student learning during instruction” (pp. 125-126). These findings appear to support Shulman’s (1986) work in building teacher self-efficacy through increased CK and PCK, and Bruner’s (1960) concept of a spiral curriculum, and one of Bartos et al.’s findings in this study was that PCK and SMKS appeared to be strongly associated as indicators of teaching efficacy.

Nilsson and Loughran (2012) embarked on qualitative study of the PCK development of prospective elementary science teachers in order to learn how PCK can be used to improve methods courses. The aim of the study was to use Content Representations (CoRe) (Loughran, Mulhall, & Berry, 2004) designed to assist prospective science teachers in conceptualizing their own learning process to gather information regarding their own learning, and then apply the results to improve their science teaching practice. The researchers noted that “PCK is a complex construct, and capturing it in practice has proved exceedingly difficult.
Yet such studies sit at the cutting edge of research in the field” (p. 700). It stands to reason that higher self-efficacy in a subject would result in emphasis on that subject as a career choice and more time devoted to study of that subject in a classroom setting.

In order to build on this body of research, if the declared goal is increased STEM participation, subsequent appropriate actions should follow in order to meet this goal. Researchers have examined the STEM deficit from many perspectives, such as gender, ethnicity and race, socioeconomic status, and parent education level. Each of these factors has a supporting body of research which informed policies and resulted in programs designed to address the specific issues contributing to the dearth of STEM participation based on the focus factor (ACT 2014, 2015; Broughton, 2013; Chen & Weko, 2009; Choi et al., 2008; Kahle, 1985; Riegle-Crumb et al., 2012). The academic preparation of teachers of science in the primary grades is a newer topic of attention in the research, and primary teachers may be in the strongest position of all teachers to make lasting contributions to solve the STEM crunch through their daily classroom practice. Increasing the self-efficacy of such teachers in both science knowledge and ability to deliver science content, while placing greater emphasis on science education in the primary grades, has the potential to increase student interest and lay foundational skills for further achievement in the sciences, and can easily be implemented through changes to teacher education programs and increased scrutiny of the implemented curriculum by LEAs.

**Elementary School Teacher Preparation**

The Liberal Studies degree roadmap, the recommended degree program for a career as elementary school teacher in California (Loyola Marymount University, 2016; San Diego State University, n.d.), was reviewed for three of the
23 campuses of the California State University (CSU) system, one in each of the geographical areas of Southern California, Central California and Northern California. The review appeared to show that completion of the proscribed curriculum is expected to impart sufficient science content knowledge in order to teach the subject in a self-contained classroom. The Liberal Studies degree roadmaps of CSU, Fresno, CSU, Long Beach and CSU, Sacramento appear to suggest that sufficient competency to teach elementary science can be gained through the completion of four survey-level classes, one in each of the domains of life and earth science, and two in the domain of physical science, with the requirement that students achieve a C- in courses in order for them to be counted toward graduation. This observation is not intended to criticize teacher education programs or post-secondary institutions, as the requirements for a pursuit of a teaching career were set forth by the California Assembly in Senate Bill (SB) 2042 (1998). The California Commission on Teacher Credentialing (CTC) was charged with overseeing implementation of SB 2042, and in accordance with the legislation, the pathway to becoming a credentialed teacher consists of three steps: subject matter preparation, teacher preparation and induction. The law calls for subject matter preparation in content areas to be “academically rigorous, providing foundational knowledge in those subjects that the teachers are authorized to teach” (CTC Professional Services Committee, 2004, p. 7A-7). When the requirements for a Liberal Studies degree are put into conversation with efforts to increase science participation and achievement, questions regarding the sufficiency of four survey-level science classes to provide elementary school teachers with content knowledge and confidence in their ability to teach science may emerge. Inadequate science content preparation of multiple subject credential holders as teachers of science may be a factor in the low achievement of students on
assessments that include a science component such as TIMSS, NAEP and the ACT.

The efficacy of TEPs in preparing elementary teachers specifically to teach science has been examined by several researchers. Herman and Clough (2014) conducted a longitudinal mixed methods study of the nature of science (NOS) understanding of 13 teachers with classroom experience ranging from 2 to 14 years after completion of a required NOS teacher education course at a midwestern United States university. Study of the NOS involves the characteristics of scientists, the role of society in directing scientific research, and the nature and construct of science knowledge. Using a pre- and post-course quantitative instrument, the researchers investigated the impact of the course content on the participants’ knowledge of the NOS. After completion of the NOS course, participants’ responses to the quantitative instrument improved from 29 out of 39 possible points to 37 out of 39 possible points. Responses that were categorized as “informed” increased from 42% on the pre-course assessment to 82% on the post-course assessment. Responses categorized as “naïve” decreased from 33% to 5%. Based on their research and the results of this investigation, Herman and Clough (2014) asserted that science teachers must “possess a deep and robust understanding of both science content and the NOS in order to effectively teach science” (pp. 1-2), and advocated for the inclusion of distinct NOS courses designed to raise awareness of the limitations, biases and social applications of the sciences.

The utility of instruction in the nature of science was investigated by Gough (2015), who promoted such instruction as means of building capacity to address issues of environmental health, well-being and economic growth. Gough’s research suggested that improvements could be made to teacher education
programs to increase CK and PCK to address “an increasing proportion of…students [who] do not have positive attitudes to science, do not see themselves pursuing a science, engineering or computing degree and do not continue their studies of science or mathematics subjects beyond the compulsory years” (p. 454). Morrell and Carroll (2003) studied the impact of several factors affecting teacher self-efficacy in teaching science, including the effects of pre-service science courses. Their investigation examined pre- and post-course STEBI-B surveys from 172 participants who were enrolled in one of three courses: Human Biology; Ideas in Physics; or Introductory Earth Science between 1997 and 2000. Paired t-tests were conducted on the pre-course and post-course STEBI-Bs. Teacher candidates in these courses who scored below 50 in PSTE on the pre-course survey exhibited a small, but significant ($p < .05$) increase in this area, but the content courses showed no effect on STOE. Methods courses yielded more significant gains in PSTE ($p$ values ranged from $< .001$ to $< .05$), but again, had no effect on STOE. From this study, it appears that among teacher candidates who possess low self-efficacy in teaching science, science content classes increased their ratings of science teaching self-efficacy, and for teacher candidates possessing low levels of personal science teaching efficacy, content courses were beneficial.

In their participant-observer qualitative study of science teacher education and how post-secondary students learn to “do” science, Feldman, Divoll and Rogan-Klyve (2009) collaborated with science and engineering professors from a Research 1 university on a study of acid drainage from an abandoned mine. The student-participants collaborated with the scientists and engineers, but were not the subjects of the study, as the authors sought to gather data regarding the professors’ dispositions toward research as opportunity for collaboration and
mentoring of students. Based on the data, it appeared that the level of expertise and knowledge of the professors had a role in determining the level of achievement of the student-participants. The researchers advocated for alignment of teacher education programs with programs that produce research scientists, writing, “Clearly, if science teachers are to help their students learn the nature of science as inquiry, know how to engage in scientific inquiry, and learn science through inquiry…they must have the knowledge and skills to make this happen” (Feldman et al., 2009, p. 443). Feldman et al. advocated for the development of “communities of practice…involved in a set of interpersonal and professional relationships, which results in the community developing around things that matter to its members” (p. 446). If this suggestion is applied to teaching and learning, then, as Feldman et al. assert, the “level of expertise of the teacher may also determine the level that their students will reach (p. 455). This philosophy of teaching and learning strongly relates to DuFour and Fullan’s (2013) work in PLCs as a method of improving teaching practice.

**Adult Learning Theory**

Adults commonly possess significant knowledge gained through experience. While this knowledge is a valuable resource, it also complicates adult learning, as most of the learning in which adult engage is a response to a need to know something, not a simple desire to learn. In *Educating the Reflective Practitioner: Toward a New Design in Teaching and Learning*, Schön (1987) called the knowledge construct *knowledge in action*, and the application of the knowledge construct *reflection in action*. Through the use of examples such as Slovakian artisans who could perceive the slightest defect in a product, or skilled physicians who could immediately and accurately diagnose a patient’s illness, Schön recommended that knowledge in action be viewed as “thinking like a
“(p. 39) in order to combine the discrete tasks and knowledge implicit to professions with the inquiry learning that contributed to true competence in professional knowledge. Reflection in action referred to the process by which adults “make new sense of uncertain, unique, or conflicted situations of practice…existing knowledge [neither] fits every case, nor that every problem has a right answer” (p. 39), requiring a new construct. In discussing the complexities of professional learning, Schön acknowledged the inherent difficulties of increased performance expectations with simultaneous lack of control over input factors that affected the outcomes, and asserted that “What aspiring practitioners need to learn, professional schools seem least able to teach” (p. 8). What appears to be missing from many professional development opportunities is the contextual, action-based and mutually reflective student-coach dialogue Schön described as being essential to adult learning. In the body of research pertaining to organizational learning Argyris (1977) identified two types of learning – single-loop learning and double-loop learning. In single-loop learning, new information easily fits into existing paradigms and is readily accepted, and in double-loop learning, underlying beliefs are challenged, which causes disruption of an existing knowledge paradigm, but may result in fundamental changes in the systems processes.

Professional development for teachers should acknowledge the tension inherent in double-loop learning processes and incorporate the tenets of Knowles’ (1962, 1972, 1974) work in adult learning theory by allowing opportunities for learning to be self-directed, purposeful, considerate of prior knowledge, respectful of adults’ readiness to learn, and relevant. Knowles (1962) proposed that teachers’ roles in the process of education should shift from “‘one who primarily transmits knowledge’ to ‘one who primarily helps students to inquire’” (p. 33), and such a dramatic change necessitates professional learning on the part of teachers in order
to support inquiry and constructivist learning activities. Knowles (1962) did not
discount the importance of content knowledge; instead, he placed great emphasis
on the pedagogical content knowledge of teachers, viewing skill in “guiding (and
serving as a resource to) students in conducting self-inquiries” as essential to
facilitating constructive learning experiences in all subject areas (p. 33). Knowles
(1962) regarded learning as a life-long process, as evidenced by this statement: “if
man is to avoid becoming obsolete, it must come to pass that the normal day of
every adult will include several hours of systematic learning…” ‘Going to school’
will become …accepted [as] a part of the adult role in society” (p. 34). In pursuit
of the creation of life-long learners, he considered teaching students how to learn
far more important than being able to spew facts, writing, “The andragogical
model is a process model…concerned with providing procedures and resources for
helping learners acquire information, understanding, skills, attitudes, and values”
(Knowles, 1974, pp. 116-117).

Teaching Teachers

The role of adult learning and professional development in supporting
reform through increased science teacher self-efficacy was studied in a literature
review by van Driel et al. (2000). The authors posited that factors contributing to
the lack of success in science education reform may be failure to take adult
learning theory into account, specifically the top-down methodology with which
much professional development is delivered, and failure to consider the teachers’
prior knowledge and beliefs that were constructed over the course of a teaching
career and how these shape the assimilation of new information. van Driel et al.
advocated for science education reforms such as implementation of teacher-
facilitated constructivist activities to engage all learners, a narrowing of the
curriculum to provide for deeper understanding of fewer curriculum topics, and
opportunities for reflection on scientific principles and the nature of science. van Driel et al. pointed out that science education reform has deviated from best practices in adult learning theory by being developed and mandated by policy makers rather than from a teacher community of practice, and as the delivery method of teacher professional develop is most often receptive in-service workshops with little follow-up, implementation of educational reforms do not proceed as intended or did not persist. The lack of attention to adult learning methodology appeared to have undermined many reform efforts in the past.

Kwakman (2003) conducted two studies of teacher workplace learning, one exploratory and the other qualitative, and examined their interaction. The first focused on defining teacher workplace learning and the effects of various workplace factors on such learning; the second used an inductive interview approach. The literature review for the exploratory study categorized professional learning into one of four activities: *reading* to collect new information; *experimenting* with something new in the context of the individual’s work; *reflection* on the processes and feedback from workplace sources; and *collaboration* for support, new ideas, or additional feedback. Sixteen teachers, 5 women and 11 men, with classroom experience ranging from 6 to 33 years were interviewed regarding their views on how they learned in the workplace. From these interviews, personal factors such as professional attitudes, appraisals of meaningfulness and emotional exhaustion, along with task factors such as pressure of work and autonomy, and work environment factors such as management support and collegial support were obtained and loaded into a survey instrument for the second study. A total of 13 factors were included in items on the survey administered to 542 secondary school teachers with a mean age of 45.8 years, a mean working experience of 20.1 years, and a gender distribution of 367 men and
170 women. Only factors that reached significance \( p < .05 \) were included in the final regression analysis. Based on participant responses to the survey regarding the frequency of professional learning activities (1 = hardly ever, 4 = often) most often engaged in by the subjects, individual professional activities appeared to be the most common, for example “Help students to learn study skills” \( M = 2.83 \), “Study subject matter literature” \( M = 2.74 \) and “Study teaching manuals” \( M = 2.64 \) had the highest means. Collaborative activities such as “Collegial classroom observation” \( M = 1.22 \), “Prepare lessons with colleagues” \( M = 1.69 \), and “Ask pupils feedback” \( M = 1.84 \) had the lowest means. The study provided evidence to support three principles of adult learning – learning had to be relevant to the context of the profession, allow for integration of prior knowledge, and be purposeful in pursuit of continuous improvement, but also appeared to demonstrate that “participation in professional learning activities depends to a large extent on personal characteristics of teachers themselves” (p. 167). In regard to the viability of schools as learning environments, Kwakman stated “the low participation in many…professional learning activities measured indicates that powerful opportunities for teachers to learn remain unused in practice. Do we have to conclude that schools are not suited for some professional learning activities to take place?” (p. 167), and advocated for institutional changes to improve the conditions for learning within schools, as “learning at the workplace requires an adequate infrastructure for learning” (p. 168).

**Teachers as Learning Leaders**

There is an oft-repeated adage in schools that the role of leadership in education is to create the conditions conducive to learning. It is somewhat ironic then, that professional learning opportunities for educators often fail to incorporate
the principles of adult learning theory. Glickman, Gordon, and Ross-Gordon (2013) stated the problem with teacher professional learning this way:

the literature on adult learning, stands in sharp contrast to the actual treatment of teachers. Many supervisors treat teachers…all the same, rather than individuals in various stages of adult growth…stamped out of teacher training institutes as identical and thereafter have no further need to be viewed as individual learners. (p. 47)

Just as the body of educational research pertaining to student learning contains examples of right and wrong pedagogy, research in andragogy points out many pitfalls of well-meaning professional development providers. Glickman et al. asserted that the structure of schools actually inhibits teacher professional development by creating an atmosphere of isolation, rather than collaboration and empowerment.

Darling-Hammond (2000) stated that the single greatest contributor to student achievement was a highly-qualified teacher. Sandholtz and Scribner (2006) suggested that quality professional development delivered in a meaningful context had the potential to affect teachers’ mindset and resultant practices in support of student learning, but asserted that the least effective form of professional development is the most commonly used. In a deficit model of professional development, teachers are passive participants in learning situations conducted by an outside entity, with little collaboration or incorporation of teachers’ knowledge. Hawley and Valli (1999) proposed that effective professional development for teachers is deeply embedded in individual school cultures, collaborative in identifying systemic issues, individual opportunities for growth and formulating solutions to perceived problems, and takes students’ present performance and desired outcomes into consideration. In their 4-year case study of a school district’s standards-based reform efforts, Sandholtz and Scribner investigated the adult learning conditions created by administrators in a medium-
sized school district in California of approximately 19,000 students with high levels of socioeconomically disadvantaged and English learners. Through collection of relevant documents such as meeting minutes, handouts, classroom observation summaries and interviews with district administrators and teachers throughout the study, the data appeared to demonstrate that implementation of the reform was undermined or contradicted by the very administrators who put it into place. The researchers appeared to find that district administrators failed to allow sufficient autonomy of site administrators and teachers to facilitate development of leadership capacity. Perceptions of the reform effort as a top-down mandate were attributed to failure to incorporate teacher voices. The perceptions of a mandate, rather than a collaborative enterprise, appeared to lead teachers to feel that the data examination process was evaluative, creating a competitive, rather than collaborative, atmosphere. Initially, according to Sandholtz and Scribner, the district professional development plan adhered to most principles of adult learning theory, but over time, “the purpose of teacher involvement centered on gaining teacher buy-in rather than capitalizing on teacher expertise” (p. 1113). The district regressed to a traditional model of professional learning, rather than the initial progressive model of organizational learning.

In order to collect information regarding capacity building in schools, King (2002) conducted a study of the teacher inquiry reform model at seven elementary schools from Spring 1997 to Fall 1999. Data to inform the study came from teacher observations, field notes and interviews. These schools practiced site-based management, had high proportions of socioeconomically disadvantaged students, but had exhibited gains in student achievement which the school attributed to teacher professional development. The teacher inquiry model requires that teachers examine their beliefs and practices and how they affected
King’s study focused on the level of teacher inquiry at the schools, as he asserted that teacher inquiry into CK and PCK (Shulman, 1986) was “necessary for ambitious school reform” (p. 243). King found that only two of the seven schools had a strong culture of teacher inquiry in all the areas that the researchers examined: teacher control over content and process; input into the school’s mission, curriculum and instruction; debate and consensus building; use of research to support actions; and collective decision making. King asserted that the administrators at these two schools “maintained a consistent focus for schoolwide professional development… and ‘buffered’ teachers from outside mandates that might otherwise interfere with their school’s efforts” (p. 251) and worked to maintain norms and built trust and collaboration while supporting the teacher inquiry model. At the five schools that were not rated as having high levels of teacher inquiry, King appeared to find that the most common professional development opportunities represented the opposite of teacher inquiry in that they were mandated, external, inconsistent, irrelevant, and lacked sufficient support to sustain them. King’s study suggested that collective schoolwide inquiry may help organizations build or maintain high levels of capacity.

Connected to the teacher inquiry model is teacher self-assessment. Ross and Bruce (2007) contended that self-assessment is an essential tool for teachers to identify areas for improvement, and advocated for training in the process to assist teachers in reflecting on their practice and soliciting input from peers and potential change agents in order to increase teaching efficacy. Through the use of an explanatory case study to explore a potential cause and effect relationship, Ross and Bruce investigated how self-assessment affected individual instructional practices. Their findings appeared to support the theory that input from peers and positive self-assessment resulted in setting of higher goals and stronger
commitment to the work, which in keeping with Bandura’s (1997) theory of mastery experiences, appeared to result in increased teaching self-efficacy and professional growth. The opposite appeared to be true for negative self-assessment. The facilitated communication from the peer input seemed to be instrumental in construction of a common language and checks for consistency that increased the self-confidence and self-efficacy of both the participants and peers. When this is put into conversation with the work of DuFour and Fullan (2013), it appears to support the creation of professional learning communities and communities of practice in order to provide the support necessary for teachers to engage in authentic self-assessment.

The concept of collaborative classroom-focused inquiry was studied by James and McCormick (2009) during the Learning How to Learn project conducted from 2001 to 2005 with participants from 40 schools in southern England. The primary investigation set out to discover if the development of specific practices could help students become more autonomous learners, with or without the presence of a teacher. This research may be related to the teaching self-efficacy of the teachers as they sought to develop learning self-efficacy in students. A subordinate component of the project researched the interaction between the learning processes of teachers and students through factor analyses of a three-section, 84-item survey with 1,900 responses. The research appeared to show that “learning how to learn cannot be separated from learning itself…it is an activity involving a family of learning practices that enable learning to happen” (p. 974). Midway through the study, researchers videotaped lessons from 27 classroom observations conducted by participant teachers, which were compared with data from interviews with the same group. The survey instrument was
administered twice, with a period of two years separating the administration. The mixed methods design appeared to support three strands of findings.

The first strand pertained to the utility of formative assessment. According to the *Glossary of Education Reform* (Great Schools Partnership, 2014), formative assessment provides data regarding student comprehension of subject matter collected during teaching and then used to guide instruction. In some classrooms, formative assessment was more meaningful than the assessment activities conducted in others (alpha = 0.76). James and McCormick (2009) attributed this difference to the teachers’ adherence to the “spirit” of formative assessment rather than the “letter” of it (p. 976), and to practices that encouraged development of student learning autonomy, to go “beyond an imitation of that model…encouraging the pupils to create their own criteria, helped them think for themselves about what might be needed to capture the meaning” (p. 976). Some teachers were able to develop open-ended assessments that contributed to student achievement more than other teachers. This ability may have been a reflection of the teachers’ own process of learning how to learn.

The second strand pertained to teachers’ beliefs regarding development of student autonomy through instructional practices (James & McCormick, 2009). Teachers who sought to build learning autonomy appeared not to view lessons as discrete tasks, but rather as a continuation of learning, much in the manner of Bruner’s (1960) spiral curriculum by “using and responding to different sources of evidence; carrying out joint research and evaluation with colleagues” (p. 977). The researchers classified this dimension as inquiry (alpha = 0.77). Thirdly, teachers’ personal values regarding education affected the breadth and depth of curriculum taught and teachers’ willingness to implement new strategies, which James and McCormick (2009) categorized as “deciding and acting together” (p.
977; alpha = 0.91), and which relates to both Shulman’s (1986) theories regarding CK and PCK, and DuFour and Fullan’s (2013) work in professional learning communities. James and McCormick’s (2009) study appeared to support the theory that the learning process for teachers should include reflection on metacognitive processes as “collaborative activity practices for teacher learning emerged as the key influence in teachers’ capacity to promote learning autonomy with their pupils” (p. 982).

Teaching teachers how to learn is closely related to the concept of self-regulated learning. Much of teacher professional learning takes place in formal, tightly structured environments that fail to take adult learning theory into account, and are often referred to in the teaching profession as “sit and get” or “spray and pray” formats (Abadiano & Turner, 2004; Colbert, Brown, Choi & Thomas, 2008; Nishimura, 2014). Over the course of a year, Hoekstra, Brekelmans, Beijaard, and Korthagen (2009) studied the informal learning processes of 32 Dutch teachers of language arts, science or social studies with a minimum of 5 years teaching experience using quantitative and qualitative methods. The goal of the study was to gain understanding of methods used by learners that supported active and self-regulated learning, which the researchers defined as active regulation of mental activities in support of learning goals. Six times during the year, participants reported via email on self-regulated learning experiences according to stem questions provided at the beginning of the study. An ANOVA was performed on data collected from teacher responses, and appeared to support the following strands of self-regulated learning activities: experimenting with self-regulated learning \( F(3, 28) = 4.188, p = .014 \); struggling with self-regulated learning behaviors \( F(3, 28) = 3.287, p = .035 \); and getting ideas \( F(3,28) = 3.116; p = .042 \). Based on these findings, Hoekstra et al. asserted that “a teacher’s focus on
new practices in combination with a meaning-oriented mental level of activities may be the most conducive of teacher change in...reform efforts” (p. 673). They further advocate for increased differentiation of support for teacher learning.

Self-regulated learning may support increased CK and PCK, but external sources of support such as professional learning communities as envisioned by DuFour and Fullan (2013) may also offer significant support. Skerrett (2010) explored the impact of communities of practice on teachers, and described a community of practice as a step toward development of a professional learning community, but that they differ in that a community of practice is simply a step toward development of a professional learning community – the process does not occur automatically, and offers capacity building opportunities for those involved. In Skerrett’s definition, a community of practice consists of professionals, “Jointly engaged in their practice, members develop, negotiate, and share meaning; create and merge identities...experience deep learning in and about their practice” (p. 648), whereas a professional learning community engages in continual inquiry to improve practice.

Through a study of 10 English teachers in an Ontario, Canada school from 2003 to 2006 consisting of interviews and examination of documents, Skerrett (2010) found that despite declarations to the contrary, the department in which these teachers worked functioned more as an administrative unit, with meetings geared more toward making decisions about the minutiae of school and information dissemination, not as a community of practice focused on teacher inquiry; analysis of sample of meeting documents did not refer to any professional learning activities. Skerrett’s review of the school district’s professional development model found that insufficient time was allocated for “effective, hands-on, and collaborative learning experiences for all teachers...[who were]
deprived of an opportunity to develop into a learning community” (p. 652). The conditions created by administrators at this school appeared to inhibit creation of conditions conducive to learning. As schools turn to new reform models in efforts to increase student achievement, the limited time available to teachers for collaborative inquiry becomes increasingly valuable. Data from reports produced by the OECD and the TIMMS point toward a plateau of academic achievement across the curriculum. While systemic issues exist and have their own bodies of research, cultures of inquiry and collaboration may be key to providing the internal coherence necessary to increase student achievement.

**Summary**

The review of the literature suggests that the issues surrounding the achievement gap in STEM fields and resulting shortage of STEM workers are multi-faceted. The literature regarding student achievement demonstrates the effects of a lack of a coherent, equitable curriculum. In its place is a curricular system that emphasizes accountability model subjects such as Language Arts and Mathematics at the expense of non-accountability model subjects. Systemic issues such as the effects of these accountability models and the leadership practices that support them on classroom instruction, autonomy of classroom practices and teacher self-efficacy may manifest in lower science achievement. The level to which pre-service teachers are prepared to teach science in TEPs, and ratings of pre-service and in-service teachers in science teaching self-efficacy may affect student achievement. In systems that emphasized science education, student achievement in science increased. The literature appears to show that teachers who had higher ratings of science teaching self-efficacy gained through teacher preparation, professional development opportunities, or self-regulated learning appeared to spend more time teaching science in their classrooms, which impacted
students’ future interest in the disciplines. Professional development opportunities that conformed to best practices of adult learning theory appeared to have positive impacts on teacher self-efficacy. This chapter reviewed the systemic issues affecting science education in school systems, and suggests that additional research in the connection between science teaching in the primary grades and overall STEM achievement is justified. The methodology for study of this issue is discussed in the following chapter.
CHAPTER 3: METHODOLOGY

This chapter outlines the method and design used in this study, as well as a review of the purpose and justification for the study. The underlying frameworks of self-efficacy and adult learning theory as they apply to the study are reviewed. A detailed description of the instrument, participant selection, administration of the instrument, and data collection procedures is provided. Procedures for analysis of the data are explained, and limitations acknowledged. A mixed methods approach was required for this study. A valid and reliable quantitative instrument for measuring science teaching self-efficacy, the STEBI-B, existed and was used. Data from interviews with teachers and classroom observations was analyzed using qualitative methods.

Purpose of the Study

The purpose of this study was to investigate the levels of self-efficacy for teaching science among primary grade teachers in a large suburban school district. Through examination of current levels of science teaching self-efficacy, science course completion during undergraduate preparation and credentialing programs, and time allocated to science instruction in primary classrooms on a regular basis, the hope was to gather sufficient data to inform policy adjustments in science teaching in the primary grades as a means of increasing student achievement and participation in STEM fields. The variables were defined as (a) current levels of science teaching self-efficacy; (b) supports and constraints for teaching science in primary classrooms (c) science course completion during undergraduate preparation and credentialing programs; (d) the kinds of science education
activities implemented by teachers; and (e) practices to support increased focus on science education.

**Research Questions**

The research questions for this study were:

RQ1: What is the practice of teaching science in the primary grades?

RQ2: How do content knowledge, pedagogical content knowledge and other teacher variables relate to primary teachers’ self-efficacy for teaching science?

**Research Design**

The frameworks of self-efficacy and adult learning theory were used to gather quantitative and qualitative data regarding science teaching self-efficacy of primary grade teachers. The STEBI-B, an instrument developed by Riggs and Enochs (1990) to study science teaching self-efficacy was administered to study participants in order to gather quantitative data. Demographic data and information regarding teacher preparation to teach science was collected through a qualitative researcher-created online survey administered to participants. Teacher content knowledge quantitative data were collected through use of a researcher-created survey consisting of released NAEP fourth-grade Science questions. The diary-interview method (Zimmerman & Wieder, 1977) was used to yield qualitative data regarding perceptions of existing supports and constraints, activities, frequency of science activities and professional development. This study sought to use these sources to provide sufficient data for triangulation of teacher self-efficacy, teacher preparation and professional development, and perceptual data in order to more fully understand the state of science education in the primary grades in the subject school district.
Participants

The participant sample were volunteers who were teaching first through third grades during the 2015-2016 academic year in one large suburban school district and in one medium-sized suburban school district in Central California. Three teachers were selected from two schools in the large school district and two teachers from the medium-sized school district for participation in interviews. These participants were contacted due to affiliation with the researcher’s school district, or through contacts made through the Doctoral Program in Educational Leadership at Fresno State.

Instrumentation

Two types of instruments, surveys and an assessment, were used to collect data for this study. The first instrument was the STEBI-B, developed by Riggs and Enochs (1990) for use in gathering data regarding science teacher self-efficacy beliefs. The second instrument was a researcher-created survey consisting of 20 released questions from the fourth grade Science NAEP exam which was used to collect quantitative data regarding teacher science content knowledge. The third instrument was a researcher-created survey designed to collect perceptual data regarding science education. Interviews were conducted using a 10-question teacher interview protocol.

Survey Design

The STEBI-B (Riggs & Enochs, 1990) was used in a paper and pencil format. The instrument includes items to collect demographic data regarding gender and number of science courses taken in high school and college. A 20-question multiple-choice format instrument pertaining to science content knowledge was created using the fourth grade Science NAEP exam released test
questions and administered online to participants through the use of a code system facilitated by the NCES website. A 25-question researcher-created instrument was used to collect data regarding the number of years of teaching experience possessed by the participants as a categorical variable of 1 (1 – 5 years), 2 (6 – 10 years), 3 (11 – 15 years), 4 (16 – 20 years), and 5 (20+ years), grade level taught as a continuous variable of Grade 1, Grade 2 or Grade 3, and ethnicity, coded as a 1 (Caucasian), 2 (Hispanic/Latino), 3 (African American), 4 (Asian American), 5 (Hmong American), 6 (Arab American), 7 (East Indian American). Interview protocol was used to collect qualitative data regarding frequency and type of science activities, constraints and supports for teaching science, and teachers’ perceptions of professional development activities in support of science teaching.

**Teacher Self-Efficacy for Teaching Science**

The STEBI-B, (Riggs & Enochs, 1990) was used to collect data regarding teacher Personal Science Teaching Efficacy Beliefs and Science Teaching Outcome Expectancies. The STEBI-B consists of 23 Likert-type items on a five-point scale with SA indicating that the respondent strongly agrees with the statement and SD indicating that the respondent strongly disagrees with the statement. The STEBI-B includes subscales for both self-efficacy (SE; alpha = .90) and outcome expectancy (OE; alpha = .77). Data regarding the validity coefficients of the number of college (SE = .27; OE = .15) and high school (SE = .12; OE = -.02) science courses taken, choice of science teaching career (SE = .58; OE = .34), use of activity-based teaching (SE = .13; OE = .31), science teaching self-ratings (SE = .58; OE = .24), and preference of science as a subject (SE = .45; OE = .29) are provided. All validity coefficients were significant at $p < .05$ or $p < .01$ with the exception of high school science courses on the outcome expectancy subscale.
Participant volunteers were assigned a code for administration of the STEBI-B corresponding to the code provided by the National Center for Education Statistics for the NAEP content knowledge exam described in the following section. Data from the STEBI-B was compared to performance on the NAEP content knowledge exam.

**Teacher Content Knowledge**

A researcher-compiled survey consisting of 20 released items from the 4th grade Science NAEP exam was used to gather data regarding the science content knowledge of participating teachers. The NAEP Questions Tool website, which is maintained by the National Center for Education Statistics (NCES), allows the public to create test instruments, restricts access to instruments through the use of access codes, and collects data regarding participant performance (NCES, 2016). Table 1 shows the list of items included on the instrument and how they are categorized on the NAEP. All questions were multiple choice format. Six questions were from the “easy” category, eight were from the “medium” category, and six were from the “hard” category. Eight were from the Earth and Space Sciences category, four were from the Life Sciences category, and eight were from the Physical Sciences category. The survey instrument detailed in Table 1 was made available online to participants through the use of the codes provided by the NCES when the instrument was constructed.

Participant-volunteers who consented to be part of focus group interviews were assigned specific codes for the purpose of tracking and triangulation of data from their instruments. The performance of these participant-volunteers on the content knowledge test was tracked and compared with data from the STEBI-B in order to triangulate science teaching self-efficacy, content knowledge, and qualitative data from focus groups regarding the perceived supports and
Table 1

NAEP-Released Items for Content Knowledge Survey

<table>
<thead>
<tr>
<th>Item</th>
<th>Question ID</th>
<th>Description</th>
<th>Year</th>
<th>Difficulty</th>
<th>Content Strand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2009-4S7 #2</td>
<td>Identify the best tool to measure rainfall</td>
<td>2009</td>
<td>Easy</td>
<td>Earth and Space Sciences</td>
</tr>
<tr>
<td>2</td>
<td>2009-4S7 #3</td>
<td>Investigate the range of bird population</td>
<td>2009</td>
<td>Easy</td>
<td>Life Science</td>
</tr>
<tr>
<td>3</td>
<td>2009-4S7 #4</td>
<td>Explain the benefit of an adaptation</td>
<td>2009</td>
<td>Easy</td>
<td>Life Science</td>
</tr>
<tr>
<td>4</td>
<td>2009-4S7 #6</td>
<td>Explain example of heat (thermal energy) transfer</td>
<td>2009</td>
<td>Easy</td>
<td>Physical Science</td>
</tr>
<tr>
<td>5</td>
<td>2009-4S7 #9</td>
<td>Predict the shape of the moon</td>
<td>2009</td>
<td>Medium</td>
<td>Earth and Space Sciences</td>
</tr>
<tr>
<td>6</td>
<td>2009-4S7 #12</td>
<td>Design an investigation to find the volume of a container</td>
<td>2009</td>
<td>Hard</td>
<td>Physical Science</td>
</tr>
<tr>
<td>7</td>
<td>2009-4S7 #16</td>
<td>Predict the location of the moon in the sky</td>
<td>2009</td>
<td>Medium</td>
<td>Earth and Space Sciences</td>
</tr>
<tr>
<td>8</td>
<td>2009-4S11 #2</td>
<td>Classify an observation as an example of erosion</td>
<td>2009</td>
<td>Hard</td>
<td>Earth and Space Sciences</td>
</tr>
<tr>
<td>9</td>
<td>2009-4S11 #5</td>
<td>Recognize that light is a form of energy</td>
<td>2009</td>
<td>Medium</td>
<td>Physical Science</td>
</tr>
<tr>
<td>10</td>
<td>2009-4S11 #6</td>
<td>Predict the relation motion of an object based on a diagram</td>
<td>2009</td>
<td>Easy</td>
<td>Physical Science</td>
</tr>
<tr>
<td>11</td>
<td>2009-4S11 #7</td>
<td>Interpret a diagram about the relative motion of an object</td>
<td>2009</td>
<td>Medium</td>
<td>Physical Science</td>
</tr>
<tr>
<td>12</td>
<td>2009-4S11 #10</td>
<td>Design a setup to test soil runoff</td>
<td>2009</td>
<td>Medium</td>
<td>Physical Science</td>
</tr>
<tr>
<td>13</td>
<td>2009-4S11 #13</td>
<td>Decide how to make a closed electrical circuit</td>
<td>2009</td>
<td>Hard</td>
<td>Physical Science</td>
</tr>
<tr>
<td>14</td>
<td>2009-4S11 #15</td>
<td>Interpret the pattern of moon shapes</td>
<td>2009</td>
<td>Easy</td>
<td>Earth and Space Sciences</td>
</tr>
<tr>
<td>15</td>
<td>2005-4S12 #2</td>
<td>Parts of a flower</td>
<td>2005</td>
<td>Hard</td>
<td>Life Science</td>
</tr>
<tr>
<td>16</td>
<td>2005-4S13 #1</td>
<td>Solid blocks in a jar of liquid</td>
<td>2005</td>
<td>Medium</td>
<td>Physical Science</td>
</tr>
<tr>
<td>17</td>
<td>2005-4S13 #7</td>
<td>Recognize the rock type based on the process of its formation</td>
<td>2005</td>
<td>Hard</td>
<td>Physical Science</td>
</tr>
<tr>
<td>18</td>
<td>2005-4S13 #9</td>
<td>Example of water condensing</td>
<td>2005</td>
<td>Hard</td>
<td>Physical Science</td>
</tr>
<tr>
<td>19</td>
<td>2005-4S14 #3</td>
<td>Identify method to compare the effectiveness of fertilizers</td>
<td>2005</td>
<td>Medium</td>
<td>Life Science</td>
</tr>
<tr>
<td>20</td>
<td>2005-4S12 #13</td>
<td>Mixture of clay, water, and sand</td>
<td>2005</td>
<td>Medium</td>
<td>Earth and Space Sciences</td>
</tr>
</tbody>
</table>
constraints for teaching science, activities and frequency of science lessons, and practices, including professional development, that may affect primary teachers’ science teaching self-efficacy.

**Interview Questions**

Interview questions explored participant perceptions regarding the priority of science education in the primary grades, the types and frequency of science activities conducted in primary classrooms, and science education professional development support activities provided for primary teachers. Interviews were allowed to take an organic form once underway, as responses and comments made by interview subjects guided the conduct of the interview process. Interview questions included:

- In your opinion, what constitutes “science education”?
- Do you enjoy teaching science?
- To what extent do you feel that your undergraduate program prepared you to teach science? Your teacher education program?
- What types of science activities do you plan most often?
- What do you think are the curricular priorities of the school district?
- What do you think your students’ perceptions of science are?
- Have you had the opportunity to attend science education professional development activities? If so, when, and what were the topics?
- Do you think that it is important for young children to learn about science?
- Do you think it is important for young children to participate in science activities?
- In your opinion, besides time, what is the greatest facilitator/inhibitor to science teaching in the primary grades?
Diary-Diary-Interview Method

Using the diary-diary interview method (Zimmerman & Wieder, 1977), six participants were asked to keep a daily diary of science teaching activities for a span of ten school days. The diary consisted of a shared access Google document for which each subject teacher and the researcher had access. Participants recorded science education events, thoughts, observations and feelings about the conduct of science education in their classrooms for each day of this component of the study.

Pilot Study

The instruments measured science teacher self-efficacy beliefs and content knowledge, and were tested through a pilot study. The survey was given to five teachers, three males and two females, employed in a large suburban school district in Central California, all of whom responded. All teachers in the sample possessed both primary and upper grade teaching experience. The survey was administered through the online assessment tool provided by the NCES using the NAEP released questions item bank. Each teacher was contacted via telephone regarding the pilot study and in return for their participation, received a token thank-you gift and my eternal gratitude. An informal focus group session was held to ascertain these teachers’ thoughts regarding the survey, and instructions for completing the survey were clarified.

Procedures/Data Collection

Data collection procedures received support from both the large suburban school district and the medium-sized school district. Information regarding the purpose of the study was disseminated by school leadership, and participant volunteers were contacted in person or via email for their participation consent.
Additionally, researcher colleagues served as assistants in data collection. A sample consent letter is included in Appendix A. Reminder emails were sent to participant volunteers who had not completed surveys within one week of receipt of the NCES NAEP content knowledge instrument code and STEBI-B instrument. After 2 weeks, an additional email reminder was sent so that as many responses as possible were solicited.

In addition to the survey instruments, face-to-face interviews consisting of volunteers from two schools in the large suburban school district and one school in the medium-sized school district were conducted. The interviews followed a semi-structured format, consisting of open-ended questions.

**Data Analysis**

**Qualitative Analysis**

Research Question 1 was addressed through the use of interviews using the questions proposed in the Interview Questions section. These sessions were digitally recorded and transcribed. The coding methods proposed by Saldana (2009) were used to code responses using indices and themes, then the indices and themes data were analyzed for trends and theories that emerged in relation to the frameworks of science teaching self-efficacy beliefs and adult learning theory. Analysis data from these interviews is contained in Appendix B. A second qualitative data collection instrument was a teacher science education activity journal, an instrument that conformed to the diary-diary interview method proposed by Zimmerman and Wieder (1977). This instrument was analyzed using the same method as the interviews to determine indices and themes of participants’ practices for teaching science. Data from this instrument is contained in Appendix C.
A matrix was used to develop categories of perceived supports and constraints in relation to the frequency and types of science activities. The matrix was analyzed for the existence of patterns between primary teachers’ perceptions of constraints and supports and the frequency and types of lessons delivered, and for the existence of patterns between primary teachers’ science teaching self-efficacy and the content and pedagogical content knowledge gained through undergraduate preparation, teacher education programs and in-service professional development opportunities.

Quantitative Analysis

A multiple regression analysis was used to examine the relationship of variables regarding teacher preparation, content knowledge, teaching experience, age, gender and content knowledge on self-efficacy beliefs. Teacher self-efficacy for teaching science and the conduct of science education in their classrooms were the dependent variables. Undergraduate preparation to develop content knowledge as measured by the NAEP assessment, teacher education program preparation to develop pedagogical content knowledge, and demographic information, including number and type of science courses taken were the independent variables. This analysis sought to determine if there was difference in the science teaching self-efficacy beliefs of teachers who scored highly on the STEBI-B and performance on the content knowledge instrument and the frequency and types of science education activities in primary classrooms.

Limitations

A significant limitation of this study was the absence of science achievement data for primary students. The PISA is not administered to elementary-age students (OECD, 2014b). The earliest grade at which the various
assessments from the NAEP suite are administered to national and state student samples is 4th grade, and student achievement in science is assessed every four years (US Department of Education, 2015). In California, the earliest grade in science knowledge is assessed is the fifth grade (California Department of Education, 2015). Without achievement data, it is virtually impossible to ascertain the current state of primary grade science education. Another limitation was the geographical emphasis of the study on Central California. While two districts are included in this study, the findings may not be generalizable to a larger or different region. The response rate to the instruments presented a limitation. Approximately 350 teachers were surveyed, and administrative support for this study was obtained at district levels and coordinated with site level administrators. Even with such support, the response rate to the instruments did not meet researcher expectations.

**Summary**

This chapter reviewed the research questions and described the proposed research design, development of the instruments and cultivation of the participant sample for this study. In addition, data collection methods and analysis procedures were described. This purpose of this study was to examine the state of science education in a large suburban school district and a medium-sized suburban school district located in Central California. The science teaching self-efficacy of primary grades teachers and the factors of undergraduate preparation, teacher education programs, teaching experience, gender, ethnicity, professional development activities and institutional priorities were examined, as was the relationship of these variables to the development of the construct. Improved preparation of primary teachers as teachers of science and increased prioritization on science education in education policy may increase student achievement and
interest in STEM fields and provide a step toward remedying the projected shortage of STEM workers (National Science Board, 2007, 2010).
CHAPTER 4: RESULTS/OUTCOMES

The results of the data analysis for this study are discussed in this chapter. The research questions were best addressed by a mixed methods design, as quantitative data regarding teacher content knowledge, self-efficacy for teaching science was collected, as well as qualitative data regarding teacher perceptions and practice of science teaching. The content knowledge and self-reported perceptions of self-efficacy for teaching science were compared with teacher perceptions regarding science education in the primary grades and the frequency and types of science education activities conducted in their classrooms. A multiple linear regression analysis was conducted to determine if teacher content knowledge and pedagogical content knowledge (independent variables) had a significant effect on science teaching self-efficacy (dependent variable). Data from interviews were analyzed and coded for indices and themes per Saldana (2009), and inter-rater reliability tested. Data regarding daily science education activities was collected through the use of a Google forms teacher journal for a period of 2 weeks of instruction using the diary-diary interview method (Zimmerman & Wieder, 1977) and analyzed for indices and themes using Saldana’s (2009) methodology. The purpose of this component of the study was to determine if significant relationships exist between teacher science teaching self-efficacy beliefs and the frequency and type of science education activities conducted.

The purpose of this study was to investigate the practice of science teaching in the primary grades, and if content knowledge, pedagogical content knowledge and other teacher variables may be related to teacher self-efficacy for teaching science. The results of this investigation could be used to determine a connection between teacher education and professional development programs and the
conduct of science education in public schools. This chapter provides information on the results of the qualitative and quantitative data collection.

The research questions for this study were:

RQ1: What is the practice of teaching science in the primary grades?
RQ2: How do content knowledge, pedagogical content knowledge and other teacher variables relate to primary teachers’ self-efficacy for teaching science?

Quantitative Data Collection Procedures

Instruments were distributed to primary teachers in a packet containing an explanation of the purpose of the study, an informed consent form, which included an option to volunteer for interviews and participation in the teacher journal activity, a ticket to take an online science content knowledge assessment, a demographic survey, and a blank STEBI-B (Riggs & Enochs, 1990). Personal contact was made with district personnel and each school site administrator to solicit participation and to review and clarify the data collection process and timeline. School site administrators who agreed to participate collected and returned completed surveys to the researcher.

The ticket in the survey packet contained instructions on how to access the science content knowledge assessment, which consisted of 20 multiple-choice type questions released from past versions of the National Assessment of Educational Progress (NAEP) 4th Grade Science assessment. The assessment used in this investigation was created by the researcher using the National Center for Education Statistics (NCES) Questions Tool available on the NCES website. Results from the NAEP assessment were reported to the researcher’s email as participants completed it. This reporting method allowed the researcher to gauge participation from school sites and make contact with school administrators.
regarding overall teacher participation rates. As school site administrators returned data to the researcher, they were entered into an Excel document and processed in SPSS for analysis at the conclusion of the data collection period.

**Demographics**

A total of 357 instrument packets were distributed to school site administrators. Of the 357 survey packets distributed, 24 were returned in the manner requested, providing matched data regarding teacher content knowledge, demographic information, and self-efficacy for teaching science. This represented a 6.7% return rate. Although a total of 39 teachers completed the NAEP assessment, a 10.9% return rate, survey packets matching their unique student identification code were not returned for 15 of the packets in order to provide additional matched data sets. A total of 75 completed STEBI-B instruments were returned, a 21.3% return rate.

Fifty-four demographic surveys were returned, a 14.6% return rate. Forty-five of the 54 (83.3%) respondents to the demographic survey were female. Five (9.3%) were male, and four declined to state, comprising 7.4% of returned demographic surveys. Data regarding age were collected as a group variable. The majority of respondents were over 40 years old. Four (7.7%) of the respondents were age 21-30. Eight (15.4%) were age 31-40. Seventeen were age 41 to 50, comprising 32.7% of participants, and an additional 17 were age 51-60, again comprising 32.7% of participants. Three (5.8%) participants stated that they were over age 60, and another three (5.8%) participants declined to state their age. Further analysis of demographic data revealed that the most common undergraduate program completed by participants was Liberal Studies \((n = 29, 55.8\%)\), followed by Child/Human Development and Social Sciences \((n = 5, 9.6\%\) each). Most participants had completed two undergraduate life science courses
(59.6%), and two undergraduate physical science courses (46.2%). The mean number of years that participants had been teaching was 18.8, and the SD = 8.77 (see Table 2).

Table 2

Demographic Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5</td>
<td>6.6</td>
</tr>
<tr>
<td>Female</td>
<td>45</td>
<td>83.3</td>
</tr>
<tr>
<td>Decline to state</td>
<td>4</td>
<td>7.4</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-30</td>
<td>4</td>
<td>7.7</td>
</tr>
<tr>
<td>31-40</td>
<td>8</td>
<td>15.4</td>
</tr>
<tr>
<td>41-50</td>
<td>17</td>
<td>32.7</td>
</tr>
<tr>
<td>51-60</td>
<td>17</td>
<td>32.7</td>
</tr>
<tr>
<td>61+</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>Decline to state</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>Undergraduate Degree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liberal Studies</td>
<td>29</td>
<td>55.8</td>
</tr>
<tr>
<td>Child/Human Development</td>
<td>5</td>
<td>9.6</td>
</tr>
<tr>
<td>Humanities</td>
<td>4</td>
<td>7.7</td>
</tr>
<tr>
<td>Biological Sciences</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>2</td>
<td>3.8</td>
</tr>
<tr>
<td>Social Sciences</td>
<td>6</td>
<td>9.6</td>
</tr>
<tr>
<td>Engineering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Computer Science</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mathematics</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Business and Allied Fields</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Allied Health Professions</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Phys Ed/Recreation Studies</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Data were collected pertaining to the number of life and physical sciences courses taken and years teaching and analyzed. Ranges, means and standard
deviation for coursework taken and years teaching are presented in Table 3. Most teachers ($n = 31; 59.6\%$) had taken two life science courses during undergraduate preparation, and most had taken two physical science courses during undergraduate preparation ($n = 24; 46.2\%$). Only one teacher had taken more than four life science courses, which corresponded to the respondent who had an Allied Health Professions degree. Six (11.6\%) teachers reported having taken more than two physical science courses. None reported having taken more than four physical science courses, and 43 (83.6\%) reported having taken one or two physical science courses (see Tables 4 and 5).

Table 3

*Ranges, Means and Standard Deviation for Courses Taken and Years Teaching*

<table>
<thead>
<tr>
<th>Courses and Teaching Experience</th>
<th>Range</th>
<th>$M$</th>
<th>$SD$</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Science Courses</td>
<td>0-6</td>
<td>.02</td>
<td>1.00</td>
<td>52</td>
</tr>
<tr>
<td>Physical Science Courses</td>
<td>0-4</td>
<td>.69</td>
<td>.90</td>
<td>52</td>
</tr>
<tr>
<td>Years Teaching</td>
<td>3-42</td>
<td>8.88</td>
<td>8.76</td>
<td>52</td>
</tr>
</tbody>
</table>

Table 4

*Number of Life Science Courses Taken*

<table>
<thead>
<tr>
<th>N of Courses</th>
<th>$F$</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>3.8</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>19.2</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>59.6</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>9.6</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Table 5

*Number of Physical Science Courses Taken*

<table>
<thead>
<tr>
<th>N of Physical Science Courses</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>36.5</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>46.2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>5.8</td>
</tr>
</tbody>
</table>

**Content Knowledge, Pedagogical Content Knowledge and Teacher Self-efficacy for Teaching Science**

Descriptive statistics were calculated for the 24 matched data sets compared to the 75 STEBI-B (Riggs & Enchos, 1990) instruments that did not have matching NAEP assessment scores. Scores from the researcher-created NAEP assessment were used to measure Content Knowledge. The minimum score on the NAEP assessment overall Table 6 contains the means, standard deviations and *n* for these data. These data appear to suggest that participants possess greater confidence in pedagogical content knowledge than in self-efficacy for teaching science, although both measures appear to be in the average range.

Table 6

*Mean and Standard Deviations for Self-Efficacy, Content Knowledge, and Pedagogical Content Knowledge*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
<th>M</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-efficacy</td>
<td>26</td>
<td>43</td>
<td>32.81</td>
<td>3.87</td>
<td>75</td>
</tr>
<tr>
<td>Content Knowledge</td>
<td>65</td>
<td>100</td>
<td>86.46</td>
<td>11.18</td>
<td>24</td>
</tr>
<tr>
<td>Pedagogical Content Knowledge</td>
<td>24</td>
<td>42</td>
<td>34.89</td>
<td>3.86</td>
<td>75</td>
</tr>
</tbody>
</table>
Items 1, 4, 7, 9, 10, 11, 13, 14, 15, 16, and 20 on the STEBI-B were designed to measure Outcome Expectancies. In this study, these items represented Pedagogical Content Knowledge. Items 2, 3, 5, 6, 8, 12, 17, 18, 19, 21, 22, and 23 were designed to measure Personal Science Teaching Efficacy Beliefs, and were used in this study to represent teacher Self-Efficacy for teaching science.

Performance on the researcher-created NAEP assessment consisting of fourth-grade released test questions represented content knowledge. The mean score on the 4th Grade NAEP assessment was 86.46. The mean score for the Outcome Expectancies subscale of the STEBI-B was 34.9 out of a possible 42 points, meaning that participants’ self-reported measure of Pedagogical Content Knowledge for teaching science was 83.1%. The mean score for the Personal Science Teaching Efficacy Beliefs subscale of the STEBI-B was 32.8 out of a possible 43 points, meaning that participants’ self-reported measure of Self-Efficacy was 76.3%. Table 7 presents the descriptive statistics for the STEBI-B items measuring Self-Efficacy for Teaching Science. Items 3, 6, 8, 19, 21, and 23 are worded in a negative manner, and therefore should have the opposite response to similar items that are worded in a positive manner. Riggs and Enochs (1990) used the term “load negatively” to describe these items. The other items on this subscale load positively. These data appear to show that participants have mixed self-efficacy for teaching science. Responses to some items such as Question 2, “I will continually find better ways to teach science,” appear to express higher Self-Efficacy beliefs, particularly in seeking out new methods for teaching science (\(M = 4.39\)), as did Question 22, “When teaching science, I will usually welcome student questions” (\(M = 4.51\)). Participants appeared to be less certain about self-efficacy as measured by Item 3, “Even if I try very hard, I will not teach science as well as I will most subjects” (\(M = 2.35\)), Item 5, “I know the steps necessary to
teach science concepts effectively” ($M = 3.63$), and Item 17, “I will find it difficult to explain to students why science experiments work” ($M = 3.57$). Item 6, “I will not be very effective in monitoring science experiments” ($M = 2.13$) was one of the items that loaded negatively. All of these questions pertained to procedural science pedagogy. The participants’ ratings for Items 3, 5, and 17 when compared to Item 6 appear to be contradictory, that participants appeared uncertain about the ability to teach experimental science, but disagreed that the uncertainty was due to an inability to monitor science experiments. Frequencies of responses to items on the Personal Science Teaching Efficacy Beliefs, (PSTE) subscale, which was used in this study to measure Self-Efficacy for teaching science are reported in Table 8.

Table 7

Means, Standard Deviations and Samples for Sample Items for Measuring Personal Self-Efficacy for Teaching Science

<table>
<thead>
<tr>
<th>Item Number and Question</th>
<th>$M$</th>
<th>$SD$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 – I will continually find better ways to teach science.</td>
<td>4.39</td>
<td>.73</td>
<td>75</td>
</tr>
<tr>
<td>3 – Even if I try very hard, I will not teach science as well as I will most subjects.</td>
<td>2.35</td>
<td>1.09</td>
<td>75</td>
</tr>
<tr>
<td>5 – I know the steps necessary to teach science concepts effectively.</td>
<td>3.63</td>
<td>.75</td>
<td>75</td>
</tr>
<tr>
<td>6 – I will not be very effective in monitoring science experiments.</td>
<td>2.13</td>
<td>.81</td>
<td>75</td>
</tr>
<tr>
<td>8 – I will generally teach science ineffectively.</td>
<td>1.95</td>
<td>.84</td>
<td>75</td>
</tr>
<tr>
<td>12 – I understand science concepts well enough to be effective in teaching elementary science.</td>
<td>3.99</td>
<td>.74</td>
<td>75</td>
</tr>
<tr>
<td>17 – I will find it difficult to explain to students why science experiments work.</td>
<td>3.57</td>
<td>.93</td>
<td>75</td>
</tr>
<tr>
<td>18 – I will typically be able to answer students’ science questions.</td>
<td>3.97</td>
<td>.71</td>
<td>75</td>
</tr>
<tr>
<td>19 – I wonder if I will have the necessary skills to teach science.</td>
<td>2.15</td>
<td>.88</td>
<td>75</td>
</tr>
<tr>
<td>21 – When a student has difficulty understanding a science concept,</td>
<td>1.97</td>
<td>.70</td>
<td>75</td>
</tr>
<tr>
<td>I will usually be at a loss as to how to help the student understand it better.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 – When teaching science, I will usually welcome student questions.</td>
<td>4.51</td>
<td>.62</td>
<td>75</td>
</tr>
<tr>
<td>23 – I do not know what to do to turn students on to science.</td>
<td>1.84</td>
<td>.75</td>
<td>75</td>
</tr>
</tbody>
</table>
Table 8

*Frequency and Percentages of Responses for STEBI-B Items in Personal Science Teaching Self-Efficacy (PSTE)*

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
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</tr>
<tr>
<td>2</td>
<td>Missing</td>
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</tr>
<tr>
<td>3</td>
<td>12</td>
<td>16.0</td>
<td>43</td>
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<td>5</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>10.7</td>
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<td>14</td>
<td>18.7</td>
<td>43</td>
<td>57.3</td>
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<td>8</td>
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<td>38</td>
<td>50.7</td>
<td>9</td>
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<td>0</td>
<td>0</td>
<td>5</td>
<td>6.7</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>11</td>
<td>14.7</td>
<td>50</td>
<td>66.7</td>
<td>9</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>6.7</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>13</td>
<td>17.3</td>
<td>48</td>
<td>64.0</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>16</td>
<td>21.3</td>
<td>40</td>
<td>53.3</td>
<td>6</td>
</tr>
<tr>
<td>21</td>
<td>15</td>
<td>20.0</td>
<td>51</td>
<td>68.0</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1.3</td>
<td>2</td>
</tr>
<tr>
<td>23</td>
<td>23</td>
<td>30.7</td>
<td>46</td>
<td>61.3</td>
<td>1</td>
</tr>
</tbody>
</table>

Responses to Items 12 and 18 in Table 7 were compared to responses to Items 2, 21 and 22. Participants rated themselves as “Strongly Agree” to “Agree” for Items 12 and 18 for teaching efficacy, yet rated themselves as “Agree” to “Uncertain” of their proficiency in elementary science concepts and ability to answer student questions. Most participants responded to Item 21 that they disagreed that they would be unable to answer student questions, but self-ratings regarding understanding of the concepts in elementary science well enough to answer student questions appeared to be less confident.
Outcome Expectancies

Outcome expectancies were measured by Items 1, 4, 7, 9, 10, 11, 13, 14, 15, 16, and 20 on the STEBI-B. Outcome expectancies was used to measure pedagogical content knowledge, or the ability of teacher action to impact student learning for science. The means, standard deviations and sample items that measured outcome expectancies are presented in Table 8. Responses to items appear to reveal average self-ratings of pedagogical content knowledge, with “Agree” responses on the Outcome Expectancy subscale of the STEBI-B being most common. Participants’ responses to Items 1, 4, 9, 11 and 14 appeared to suggest that although they believed that teacher action to employ effective practices could overcome a science education deficit, responses to Items 7, 10, 13 and 15 may suggest that participants may attribute student difficulties in learning science to factors external to teacher ability in teaching science. Responses to Item 4, “When the science grades of students improve, it is often due to their teacher having found a more effective approach” ($M = 4.00$) are related to participant ratings of self-efficacy for teaching science, but responses to Item 13, “Increased effort in science teaching produces little change in some students’ science achievement” ($M = 2.29$) appear to show that even when participants increased effort in science education they were not sure that it would result in increased student achievement. While responses to Item 14, “The teacher is generally responsible for the achievement of students in science” ($M = 3.77$) appear to demonstrate that participants possess a high level of feeling accountable for student achievement in science, responses to Item 7, “If a student is underachieving in science, it is most likely due to ineffective science teaching” ($M = 3.32$) and Item 10 “The low science achievement of some students cannot generally be blamed on their teachers” ($M = 3.16$) appear to deflect accountability,
as the mean is skewed more toward “Uncertain” than “Agree.” Responses to Item 20, “Given a choice, I will not invite the principal to evaluate my science teaching” ($M = 2.27$) regarding use of science teaching as an administrative evaluation tool appear to suggest that participant confidence in the ability to teach science effectively may be lower than the ratings for the other items on this subscale. This dichotomy will be discussed more in the analysis of the qualitative data collected from interviews and the teacher science activity journal instruments. Table 9 contains the means, standard deviations and samples for responses to STEBI-B items in Outcome Expectancies. Table 10 contains the frequencies and percentages for responses to STEBI-B items measuring Outcome Expectancies.

**Table 9**

**Means, Standard Deviations and Samples for Sample Items for Outcome Expectancies (Pedagogical Content Knowledge)**

<table>
<thead>
<tr>
<th>Item Number and Question</th>
<th>$M$</th>
<th>$SD$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – When a student does better than usual in science, it is often because the teacher exerted a little extra effort.</td>
<td>3.67</td>
<td>.94</td>
<td>75</td>
</tr>
<tr>
<td>4 – When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.</td>
<td>4.00</td>
<td>.70</td>
<td>75</td>
</tr>
<tr>
<td>7 – If students are underachieving in science, it is most likely due to ineffective science teaching.</td>
<td>3.32</td>
<td>1.03</td>
<td>75</td>
</tr>
<tr>
<td>9 – The inadequacy of a student’s science background can be overcome by good teaching.</td>
<td>3.89</td>
<td>.67</td>
<td>75</td>
</tr>
<tr>
<td>10 – The low science achievement of some students cannot generally be blamed on their teachers.</td>
<td>3.16</td>
<td>.97</td>
<td>75</td>
</tr>
<tr>
<td>11 – When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.</td>
<td>3.71</td>
<td>.88</td>
<td>75</td>
</tr>
<tr>
<td>13 – Increased effort in science teaching produces little change in some students’ science achievement.</td>
<td>2.29</td>
<td>.90</td>
<td>75</td>
</tr>
<tr>
<td>14 – The teacher is generally responsible for the achievement of students in science.</td>
<td>3.77</td>
<td>.71</td>
<td>75</td>
</tr>
<tr>
<td>15 – Students’ achievement in science is directly related to their teacher’s effectiveness in science teaching.</td>
<td>3.51</td>
<td>.94</td>
<td>75</td>
</tr>
<tr>
<td>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.</td>
<td>3.57</td>
<td>.93</td>
<td>75</td>
</tr>
<tr>
<td>20 – Given a choice, I will not invite the principal to evaluate my science teaching.</td>
<td>2.27</td>
<td>1.10</td>
<td>75</td>
</tr>
</tbody>
</table>
Table 10

Frequency and Percentages of Responses for STEBI-B Items in Outcome Expectancies (Pedagogical Content Knowledge)

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1.3</td>
<td>10</td>
<td>13.3</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>4.0</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2.7</td>
<td>18</td>
<td>24.0</td>
<td>16</td>
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<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>5.3</td>
<td>9</td>
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<tr>
<td>10</td>
<td>2</td>
<td>2.7</td>
<td>21</td>
<td>28.0</td>
<td>18</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>1.3</td>
<td>7</td>
<td>9.3</td>
<td>16</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>10.7</td>
<td>50</td>
<td>66.7</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>8.0</td>
<td>11</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>22.7</td>
<td>9</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>2.3</td>
<td>9</td>
<td>12.0</td>
<td>22</td>
</tr>
</tbody>
</table>

20  missing

Content Knowledge and Outcome Expectancies -

Effects on Efficacy Beliefs

Regression analysis was performed on the 24 sets of matched data using performance on the NAEP assessment created for this study as a measure of Content Knowledge and the Outcome Expectancies subscale of the STEBI-B as a measure of Pedagogical Content Knowledge as the independent variables. Their effects on Self-Efficacy was the dependent variable. The purpose of this analysis was to determine if teacher Self-Efficacy for teaching science could be predicted by performance on the NAEP assessment (Content Knowledge) and self-reported measures of pedagogical content knowledge (Outcome Expectancies subscale of the STEBI-B). The regression equation is $Y = 30.09 + .28 \text{OutcomeExp} - .09 \text{NAEP}$. This model is not significant ($F(2,21) = 1.73, p = .20$, adjusted $r^2 = .06$. Although only 24 matched sets of data were available for analysis, the model had an adjusted $r^2 = .06$, which suggested that additional data may have found significance. These data are presented in Tables 11 and 12.
Table 11

Analysis of Variance for Teacher Self-Efficacy for Teaching Science, Content Knowledge Performance and Pedagogical Content Knowledge

<table>
<thead>
<tr>
<th>Model</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>r^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>41.23</td>
<td>2</td>
<td>20.61</td>
<td>1.73</td>
<td>.20</td>
<td>.06</td>
</tr>
<tr>
<td>Residual</td>
<td>250.73</td>
<td>21</td>
<td>11.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>291.96</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12

Regression Analysis for Teacher Self-Efficacy for Teaching Science, Content Knowledge Performance and Pedagogical Content Knowledge

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>Outcome Exp</td>
<td>.28</td>
<td>.20</td>
</tr>
<tr>
<td>NAEP Score</td>
<td>-.09</td>
<td>.07</td>
</tr>
</tbody>
</table>

A second regression analysis was performed using the dependent variable of the Personal Science Teaching Self-Efficacy Beliefs (PST-E) subscale of the STEB-B and the predictor variables of gender, number of life science courses completed, number of physical science courses completed, years teaching, years teaching the primary grades and outcome expectancies. The regression equation is

\[ Y = 35.11 - .27\text{OutcomeExp} + .04\text{NAEP} - 5.45\text{Age} - 1.15\text{NoLifeSci} - .19\text{NoPhySci} + .49\text{YrsTch} - .40\text{YrsPrim} + 9.10\text{Gender}. \]

This regression model predicting efficacy beliefs from gender, number of life and physical sciences courses taken, total years teaching and years teaching primary and outcome expectancies was not significant \(F(3,8) = .80, p = .65\), adjusted \(r^2 = -.17\). Data from the Analysis of Variance are
reported in Table 12. Unstandardized coefficients, standard coefficients, \( t \)-tests and their \( p \) values are reported in Table 13. None of the dependent values in this analysis is significant, although this finding may be attributed to the small number of matched data sets available for analysis (\( N = 24 \)). Table 14 presents the multiple regression analysis data for the independent variables of gender, number of life and physical science courses taken during undergraduate preparation, the score on the NAEP assessment, years of teaching primary grades, age and pedagogical content knowledge as measured by the Outcome Expectancies subscale of the STEBI-B on Science Teaching Efficacy Beliefs.

Table 13

*Analysis of Variance for Efficacy Beliefs by Gender, Number of Life Science Courses Taken, Number of Physical Science Courses Taken, Content Knowledge, Years Teaching, Years Teaching Primary Grades, Age and Pedagogical Content Knowledge*

<table>
<thead>
<tr>
<th>Model</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>( F )</th>
<th>( p )</th>
<th>( r^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>120.10</td>
<td>8</td>
<td>15.01</td>
<td>.80</td>
<td>.64</td>
<td>.68</td>
</tr>
<tr>
<td>Residual</td>
<td>56.15</td>
<td>3</td>
<td>18.72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>176.25</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 14

*Regression Analysis for Efficacy Beliefs by Gender, Number of Life Science Courses Taken, Number of Physical Science Courses Taken, Content Knowledge, Years Teaching, Years Teaching Primary Grades, Age and Pedagogical Content Knowledge*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>( t )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome Expectancies</td>
<td>-.27</td>
<td>-.18</td>
<td>.81</td>
<td>.48</td>
</tr>
<tr>
<td>NAEP Score</td>
<td>.04</td>
<td>.11</td>
<td>.24</td>
<td>.79</td>
</tr>
<tr>
<td>Age</td>
<td>-5.45</td>
<td>-1.36</td>
<td>-2.01</td>
<td>.138</td>
</tr>
<tr>
<td>No. of Life Science</td>
<td>-1.15</td>
<td>-.33</td>
<td>-1.43</td>
<td>.69</td>
</tr>
<tr>
<td>No. of Phys Science</td>
<td>-.19</td>
<td>-.05</td>
<td>-1.06</td>
<td>.95</td>
</tr>
<tr>
<td>Yrs. Teach</td>
<td>.49</td>
<td>1.12</td>
<td>1.44</td>
<td>.25</td>
</tr>
<tr>
<td>Yrs. Primary</td>
<td>-.40</td>
<td>-.79</td>
<td>-.90</td>
<td>.44</td>
</tr>
<tr>
<td>Gender</td>
<td>9.10</td>
<td>.66</td>
<td>1.45</td>
<td>.24</td>
</tr>
</tbody>
</table>
Qualitative Research Results

Both research questions contained a qualitative component of inquiry into teaching practices and teacher perceptions of self-efficacy for teaching science. Ethnographic interviews were conducted with 11 teachers from three schools. The three schools were chosen due to the diversity of socio-economic demographics represented by their student populations, which allowed insight into how teaching practices and experiences of both teachers and students differed according to the school demographics. One school qualified for funding under Title 1 of the Elementary and Secondary Education Act of 1964. According to the law, the purpose of such funding is to increase educational opportunity for students of poverty. The second school’s population represented a middle class demographic, while the third was located in an affluent area of Central California. Additional data were collected regarding the practice of teaching science in primary classrooms via a teacher science teaching activity journal, the results of which were analyzed for indices and themes (Saldana, 2009). This section summarizes the qualitative data gathered. All participants were identified by number only, and also represented diversity in teaching experience, grade levels taught, undergraduate preparation and gender.

Interview Themes

Seven themes emerged from the participant interviews. Within these themes, indices were identified by identifying recurring phrases or concepts. Data regarding themes and indices are presented in Table 15.

Assessment

The pressure teachers appear to feel is placed on them by assessment was remarked upon by every teacher interviewed, even though none of the interview
Table 15

Themes and Indices of Interview Data

<table>
<thead>
<tr>
<th>Themes</th>
<th>Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment</td>
<td>Frequency of assessment&lt;br&gt;Pressure to have students perform/teacher evaluations&lt;br&gt;Loss of teacher autonomy due to emphasis on assessment</td>
</tr>
<tr>
<td>Language/Literacy Arts</td>
<td>Absorption/ Integration of science education into ELA&lt;br&gt;Science education reduced to vehicle for ELA instruction&lt;br&gt;School district priorities emphasize ELA and Math</td>
</tr>
<tr>
<td>Professional Development</td>
<td>PD for ELA and Math strongly emphasized over other subjects&lt;br&gt;Uncertainty regarding transition to NGSS/lack of training</td>
</tr>
<tr>
<td>Undergraduate Preparation</td>
<td>Reliance on textbook to teach science&lt;br&gt;Few science courses taken&lt;br&gt;Ineffective pedagogy in college courses</td>
</tr>
<tr>
<td>Teacher Preparation Program</td>
<td>Low self-efficacy to teach science after completion&lt;br&gt;Insufficient experience with teaching science&lt;br&gt;Focus on theory rather than practicality; little hands-on</td>
</tr>
<tr>
<td>Resources</td>
<td>Few resources provided for science education&lt;br&gt;Frequent expenditure of personal funds for science materials&lt;br&gt;Lack of time/pressure to focus on tested subjects</td>
</tr>
<tr>
<td>Attitudes Toward Science</td>
<td>Students love science, but have difficulty identifying with curriculum as it is taught&lt;br&gt;Science as subordinate to ELA and Math</td>
</tr>
</tbody>
</table>
questions specifically addressed assessment. Three areas emerged from this theme: the frequency of assessment, fear that student performance was used as a tool to evaluate teachers, and assessment’s effects on the curriculum. Several teachers expressed frustration with the amount of assessment. They reported feeling that assessment could be used as an evaluative tool by administration regarding their teaching effectiveness, leading to pressure to have students perform well, thus reducing the teacher’s role in education and the level of autonomy within their classrooms.

The interview participants also intimated that the emphasis on assessment reduced students to test-takers, while simultaneously denying them access to the full curriculum. One teacher reported,

…the school’s under pressure to do well on the SBAC [Smarter Balance Assessment Consortium] so their scores look good. The SBAC is determined by someone higher than the school. The administration of the school feels pressured to score well and so that pressure gets transferred to us, so suddenly we’re spending a lot of time trying to figure out what’s on the SBAC so we can teach that way.

Participants also reported feeling that there was too much emphasis on assessment, and that the frequency of assessment cut into instructional time, which again, may deny students access to the full curriculum. One teacher described this, saying,

Obviously we’re assessed in language arts and math. Continuously. The district provides assessments, so we’re using area assessments. We have area teams that work on writing assessments. We have curriculum and instruction department for our district that provides us with all kinds of resources for language arts and math.

Another teacher remarked,

We’re trying to kill two birds with one stone. We’re trying to teaching the reading standards which is what they’re [students] being assessed on, with the Common Core and the SBAC, and it’s heavy non-fiction text.
The current accountability model with emphasis on assessment in ELA and Math has led to many teachers conflating literacy activities with science education.

Another teacher remarked on this, saying,

We’re assessed on language arts and math constantly. I’d pretty much like kids to be able to just show what they know, and I’m pretty happy with that. If I can get that, I’m happy regardless of the outcome. Maybe that’s not the most politically correct thing to say, but that’s how I feel as an educator. I think that sometimes when you know something else, another assessment’s coming for language arts of math, and you know, okay, do we review this [ELA or Math] or do we do that [curricular subjects other than ELA and Math]?

Additional comments in this theme included:

Science has not been given to me as a priority. I’m dictated by what’s coming from above me and so I don’t have a huge amount of time in my day to do pure science education because the powers above me are not dictating my day that way.

It’s not the tested curriculum.

It’s leading our education. It’s leading how teachers’ lessons go. This is where I have to get to and I’ve only got so many hours in a day. I have to do this.

**Literacy/Language Arts Instruction**

A recurring index during teacher interviews was concerted effort on the part of interview participants to teach science by integrating aspects of science education into ELA instruction. One teacher stated,

I think we’re more into the ELA standard and pushing that into science so that they have the basic reading fundamentals, and hoping they’re applying that to their science non-fiction reading.

Such efforts may reveal recognition by teachers that students enjoy science and deserve access to a full curriculum. These efforts may also reveal a subordinate emphasis on science in comparison to ELA caused by an unconscious reductionist attitude toward science education in the curriculum, and misidentification of ELA activities as science education.
One teacher reported,

The science we’ve done this year has been mostly about the study of animals and it’s all integrated with writing. We did a lot of informative writing all winter really. We would study an animal, read about an animal, watch videos on that animal and then write an organized paragraph or two on that animal.

In regards to the possibility of secondary emphasis on science, another teacher remarked,

Yeah, we’re definitely doing a lot of reading. We’re using it for writing, so we have to write, obviously read and write all the time. We’re trying to find science articles and things that are aligned with our standards, but yet at the rigor and at the right reading levels that we need to make it also enhance our ELA curriculum, and then that goes along with the writing, too.

An additional index pertained to decreased educational opportunities among students from socio-economically disadvantaged backgrounds. Several teachers discussed lower rates of student exposure to print and literacy in their homes during the primary grades, which translated to reading difficulties that teachers addressed by intensifying reading instruction. As one teacher commented on the nexus of Assessment and Literacy/ELA,

I think there’s kind of this fear that we really need to focus on ELA and math. That data for our kids is going to be shown to everybody, and we don’t want to be embarrassed. Because I think that adds to the stress to where we feel more confined to what we can teach because it’s what we should teach because that’s what we are being assessed on, because they’re being assessed on [ELA and Math].

Additional comments in this theme included:

If there’s not as much emphasis on reading at home or books at home then they’re coming at you maybe further away from that than kids from other backgrounds.

It won’t help them in science if I can’t get them to be good readers. That has to be my priority.
You have your small groups in the office in the afternoon [for intervention services] and I have definitely pulled my small reading groups and done non-fiction texts with them that connect with what we are doing in science.

We do a lot of research based. A lot of kids researching items....a lot of it is just research-based. So the kids have a topic and they are navigating through already designated sites where they’re only allowed to go. And they’re learning information and usually creating some type of project based on their research, whether it’s an actual research item...Most recently, they created an actual trifold. They also created learning posters, where they presented kind of like a jigsaw...They had to be the experts and they had to do their presentation to incorporate their listening and speaking standards, which are part of the ELA standards. Those are the types of products they’re creating, so it’s a lot of us using that content of science embedded within our English/Language Arts blocks.

**Professional Development**

Teachers reported a dearth of professional development activities for science. Only two of the eleven interview participants had attended a science professional development within the last 3 years, and knowledge of the professional development opportunity was acquired through a chance encounter while on a ski trip. For all other teachers, many years had passed since their last science education professional development opportunity, some as long as two decades. The lack of professional development opportunities appeared to negatively affect teacher self-efficacy for teaching science. As one teacher remarked,

> Reading a story to someone, and discussing the elements of the story seems much easier than discussing a topic where there can be lots of questions that are hard for us to answer or [that] we can’t answer.

Another teacher stated,

> How about some training? It would be really nice for this district to bring in some training. Put us through training...I’m in a three year math cohort, [in] which I feel like I’m learning a lot. I’m a very strong reading teacher, not so strong math. Well, maybe after that I’ll go into some science training if they offered it.
Several teachers discussed how assessment drives the professional development opportunities they are offered. An especially interesting comment was,

Not that I can think of. I’ve attended a lot of, a lot of workshops and most of them have been in reading and math. I don’t remember really attending a science workshop, to be honest with you.

Additional comments in this theme included:

I have attended many ELA, many math and many technology seminars and conferences after that, but that was my only science [one].

I did go to some outdoor science camp professional developments…was a long time ago, but of course what I learned there I can’t realistically really do. I could theoretically. We could go on nature walks and stuff like that around the school, but it’s hardly realistic.

Not recently. Not since I was first a teacher. Like I said, we did the AIMS training when I first started and I taught at another school. We got that. And then, very minimal. It’s declined as I moved from upper grade to primary, because if anyone’s going to get science PD, it’s not going to be the third grade, it would be the fourth or fifth grade.

**Undergraduate Preparation**

The majority of respondents to both the STEBI-B and the interview participants possessed degrees in Liberal Studies, the degree path for which prescribes completion of two life science courses and two physical science courses. In discussing undergraduate preparation, one respondent remarked,

I don’t think it prepared us enough. You took your basic science classes…Liberal studies.

From other participant responses to the interview question regarding adequacy of undergraduate preparation, it appears that most participants perceived their science preparation during their degree program as deficient. One participant responded,

I just remember taking one…I took my science content to graduate, to get my undergraduate bachelor’s degree, but as far as how to teach and how to
integrate science into my everyday curriculum, it was one class and I don’t feel it prepared me at all.

Another participant stated,

The other classes are, like I said, I took notes, passed the test, sat there and listened to the teacher, like most of those undergraduate college classes. Meh.

The data suggested that teachers enter classrooms with deficient content knowledge even after completion of a bachelor’s degree program.

Additional comments in this theme included:

No, not really at all. I mean that doesn’t mean that I can’t read some books and get some things of mine that pertain to maybe first grade curriculum. In college, it really didn’t prepare us.

Lecture, read the book and assignments.

You know you can sit in classroom but until you actually go out in the field it just feels like a continuation of high school. You’re learning it, but you’re not really applying it and so…”

**Teacher Preparation Program**

All interview participants reported taking one class during their teacher education program that focused on science pedagogy, either by itself, or in conjunction with math or social sciences pedagogy. As one teacher pointed out,

There was just one science class and again it was more of a lecture type of program. I didn’t really get a whole lot out of it.

All participants appeared to opine that taking one class on science pedagogy during their teacher education program was inadequate preparation for teaching classroom science. One of the teachers stated,

I remember doing a science lesson, I remember doing a week of science or something like that. That’s not enough to be able to teach. I don’t think it’s enough. I think it’s come with experience. I’ve come across a lot of teachers along the way that I’ve taught with, or new teachers, even, that I think back up when it comes to science.

Another teacher commented,
it gave me good ways that I would want to teach science, but actually like... I don’t know. Actually to walk in and be like, ‘Now I can teach science,’ I don’t know about that…

Additional comments in this theme included:

The teacher education program didn’t… I didn’t feel equitably prepared to teach science. I learned on the job.

I think it was the idea behind it. Lots of hands-on. Lots of experiments. Those theories were taught to me for sure. It’s just the reality of implementing them. They leave out like ‘Who’s going to buy me all these resources?’ Those questions they don’t mention in the program and you get to your own room and so much of what you’d like to do you’d have to be willing to pay for on your own so that’s an issue.

None. It didn’t at all. Well, I can’t say that. I did take geology and I did take biology. It taught me about frogs and the environmental studies but that’s about it.

Resources

Several resources were identified by teachers as being essential for teaching classroom science: time, materials, professional development and funding.

Finding time to teach science in an accountability model appeared to be the most common index of this theme. As one teacher commented,

I think if we had the time, if we had the resources, if it was the focus, it wouldn’t be what I perceive as a daunting task.

The second most common index was comments regarding expenditure of personal financial resources on science education materials. One teacher comment summed up most of these indices:

I think time is a big part of it. I think the interest is there I think, I wouldn’t say we have the best materials provided to us… I think there are plenty of things out there that we can access and we can find. I think the biggest inhibitor is the time, is just getting it in there.

Another teacher reported,

I want us all to plant seeds and grow them in pots, but am I willing to spend all that on my own money? Am I willing to? I’d love to watch ladybugs
hatch and caterpillars. I’d love to have a tank of tadpoles and watch them turn into frogs, but who’s going to – that’s my own money.

Three of the 11 teacher-participants suggested that additional classroom personnel would aid in planning, preparation and classroom management of hands-on science education activities, which may be interpreted as a sincere desire to increase science education classroom activities, or as a desire to abdicate responsibility for teaching classroom science, a question which segues into the final theme, Attitudes Toward Science.

Additional comments included:

My priority, I have spent a lot of my own money but it’s been mostly on books because even more important than science is I’ve got to get them reading.

To a certain extent also materials, because it seems like there is a wealth of materials for math and the ELA. You are sometime scrambling to find the materials or paying for it out of your pocket more often than not. Like everybody else, I do that a lot, pay for that out of my pocket and just accept that it is part of my job.

It’s been a long time since we received a new science book or a new science, any new science support or anything that’s provided in that type, it’s been a while. I don’t remember what year it was that we received science materials. 2007.

**Attitudes Toward Science**

All interview participants reported great affinity for science, and reported that students exhibit great enthusiasm for the subject. As one teacher commented about students,

that light inside them hasn’t been dulled yet at such a young age, so they think it’s fascinating to learn about a jaguar or a fossil or even watch a plant grow. Those things excite them at the core and energize them and I think it’s part of the innocence of being so young.

Another teacher commented on her personal interest in science, saying,
I love it. It’s a good pathway to a lot of different curriculum areas…There has to be a way for them to connect to it, for it to be meaningful for them, and science is a good pathway for that.

However, the effects of accountability models on both teachers and students may be illustrated by comments such as this:

I think it’s a short window where you get that enthusiasm. [And the curiosity?] Oh, it’s killed by the next couple of years. It really is. I know that from my own three children. It’s because you just get this big heavy textbook plopped down in front of you and have to just read it and then answer questions on it, take a test on it. It’s enough to just kill you.

Several teachers alluded to the practice of embedding science education in ELA lessons, saying,

It’s just a way to teach reading. When we teach science in third grade, and maybe this sort of answers that constitutes science education, when we teach science we’re teaching reading through science.

This comment was especially illustrative of how a reductionist viewpoint of science affects the conduct of science education and impacts teacher self-efficacy for teaching science.

Additional comments included:

I think it’s crucial to building their enthusiasm for learning and keeping them in tune with the world and exploring the world that they live in and seeing it in new ways.

By the time you’ve tried to get through all that, you’re just exhausted and the day’s almost gone. I guess I’m just saying whether I’m great at teaching science or whether I believe in it or not isn’t even barely the point. Because I don’t have a huge amount of say in it anyway.

You can’t just read about it. We have to be able to see it in action, so when we talk about weather patterns, we go outside to observe them. We’re touching the crinkly fall leaves that have fallen on the ground, we’re smelling the air, and then writing about it, talking about it, drawing pictures of what we observed, things like that.
Science Education Activities Teacher Journal

A group of 36 study participants were given access to a Google Forms teacher journal that conformed to the diary-diary interview method proposed by Zimmerman and Wieder (1977). Over the course of 2 weeks, the researcher sent daily invitations to participants for them to post a brief description of the science education activities in their classrooms. The entries were analyzed using Saldana’s (2009) method of coding qualitative data. Of the 61 journal entries, the primary activity (reading, writing, researching, editing and discussion) in 30 (50%) of the entries would most likely be considered an ELA task. Students in the participants’ classrooms engaged in reading their textbooks, various books and poems, listening to recordings of their textbook and watching science videos online and at classroom centers, and close reading of articles about animals and plants. The students created word walls, worked with new vocabulary and participated in class discussions. They learned about text features of written material, read for the purpose of researching a topic, and wrote in their science journals. They composed informative and opinion paragraphs with and without the use of technology.

Sixteen (26.2%) entries indicated that no science education activities occurred on that day. It is interesting to note that none of the activities in this component of the study focused on physical science, and only two of the entries involved earth science – the first lesson introduced the water cycle and included a teacher demonstration of making a cloud in a bottle, and the second was a review of the previous water cycle activity lesson. From the data collected, life science appears to be the most common type of science taught in primary grade classrooms, as butterflies, owls, chicks, Arctic animals, ants, ocean life, biomes, goats, sheep, root vegetables, seeds and flowers were topics of study. Seven of the
lessons annotated on this journal included a hands-on component in which students were able to interact with materials. These included handling of products from sheep, a “root hunt” mini-field trip around campus and harvesting of vegetables from a classroom garden before looking at them under a microscope, and making terrariums and observing capillary action. Twenty-two (36.1%) of the activities entered into the journal conformed in some manner to the Next Generation Science Standards (NGSS) for one of the grade levels studied by having some activity that pertained in some way, no matter how obliquely, to the NGSS strands of Heredity, Biological Evolution, Earth Systems or Ecosystems (Carnegie Corporation of New York and Center for Advanced Study, 2011). Two (3%) responses indicated that students took a science assessment that day. It appears that several schools were preparing for Open House, so many participants indicated that an integrated science and art project was being prepared to showcase at the event. When viewed through the lens of teacher self-efficacy, one especially interesting entry was this:

This week we are learning about social studies and not doing science. Boo! I cannot help you. Unfortunately, I cannot teach both science and social science at the same time. I wish I could.

**Summary of Qualitative Research**

The qualitative research provided significant insight into the complexities confronting classroom teachers. It appears that teachers have been presented with competing priorities and limited resources, and are attempting to perform to expectations while balancing systemic resistors such as lack of resources, an emphasis on assessment and uneven preparation to teach science. In continued efforts to teach what teachers categorize as “science,” they have attempted to integrate some science teaching into ELA activities. Many primary teachers are concerned with students’ readiness to learn, which may affect the frequency of
science education activities, and the amount of class time that teachers feel that they have to devote to science. Most teachers felt underprepared to teach science, from both undergraduate and graduate preparation, as well as a lack of science education professional development activities. All of these factors may combine to negatively impact teacher self-efficacy for teaching science.
CHAPTER 5: DISCUSSION/SUMMARY/CONCLUSION

Introduction

Although the conduct of science education has been included in economic and political dialogues for most of the past century, the recent growth of new industries centered on science and technology has intensified discussion of the role of science education in preparing workers for these industries. The phrase, “College and Career Ready” entered the national vocabulary, an occurrence that may partially be attributed to the 2010 reauthorization of the ESEA, which include national standards for college and career readiness (U.S. Department of Education, 2010). National academies and agencies have produced numerous reports raising the alarm on the subject and decrying the conduct of science teaching, yet education policies that have been enacted during this period of debate tend to emphasize ELA and Math education and marginalize science education. Teacher education programs for elementary school teachers appear to strongly focus on reading instruction, and in-service teachers are afforded significant professional development opportunities for ELA and Math. It appears that this is not case for science education. Inquiry into how to prepare and develop teachers to facilitate science education that inspires student learning while providing a basis for economic growth is essential to progress in this field.

Purpose of the Study

The purpose of this study was to examine the state of primary grades science education in two school districts in Central California. The data collected for this study may reveal connections between current school accountability models and the conduct of science education in the primary grades. Education policies that emphasize and direct the majority of resources toward ELA and Math
instruction and professional development may negatively impact primary grade teacher self-efficacy for teaching science and negatively influence the conduct of science education for young learners.

Research Questions

RQ1: What is the practice of teaching science in the primary grades?
RQ2: How do content knowledge, pedagogical content knowledge and other teacher variables relate to primary teachers’ self-efficacy for teaching science?

Summary of Findings

Teacher interviews and a science education activity journal conforming to the diary-diary interview method (Zimmerman & Wieder, 1977) were used to collect data to answer research question one. Data to answer research question two was collected through use of the STEBI-B (Riggs & Enochs, 1990) instrument to measure Self-Efficacy for Teaching Science and Pedagogical Content Knowledge through the Outcomes Expectancies subscale, a researcher-created science content knowledge instrument constructed of released test questions from the 4th Grade NAEP for Science to measure Content Knowledge, and a researcher-created demographics survey. These data were analyzed using descriptive statistics, frequencies, and multiple linear regression.

Data from interviews and the science education activity journal suggested that the curriculum in these classrooms was driven by assessment paradigms. Interview data also appeared to suggest that teachers did not feel adequately prepared or supported to teach science, and that the majority of science education activities carried out in classrooms were, at their core, ELA or literacy tasks. When the data from the interviews were examined in conjunction with the results
of the STEBI-B, there appeared to be contradictory evidence regarding expressed teacher self-efficacy for teaching science and the actual conduct of science education. Participants reported having average self-efficacy for teaching science; however, interviews with teachers and the science education activity journal appeared to reveal that the majority of respondents engaged in ELA activities to teach “science.” This may reveal a failure to discover or settle upon a common definition regarding what constitutes “science education.” It may also reveal misconceptions about the conduct of science teaching and substitution of subjects with which teachers are more confident in their ability to teach. Policy documents, such as the *California Common Core State Standards: English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects* (California Department of Education, 2013), and the lack of professional development in helping teachers interpret them, may be compounding teachers’ conflation of ELA activities with science education. This publication was referred to by one teacher in the interviews as the Common Core State Standards for Science, which do not exist. The Science Content Standards adopted in 1998 were replaced in 2013 by the adoption of the NGSS (CDE, 2015).

The average of the STEBI-B questions on the Outcome Expectancies subscale was 3.88 on a five-point scale, indicating that most respondents rated themselves average in pedagogical content knowledge. However, if teachers cannot correctly identify science education activities and substitute the teaching of science with teaching of ELA activities, the Self-Efficacy results from the STEBI-B in this study may be more reflective of self-efficacy in teaching ELA than for teaching science.

The Personal Science Teaching Efficacy Beliefs (PSTE) subscale of the STEBI-B was used in this study to measure self-efficacy for teaching science. The
average of the STEBI-B questions on this subscale was 3.88 on a 5-point scale, indicating that most respondents rated themselves average in science teaching self-efficacy. The Outcomes Expectancy (OE) subscale of the STEBI-B was used to measure Pedagogical Content Knowledge. The researcher-created NAEP instrument was used to measure Content Knowledge. The number of participants completing the NAEP instrument was small ($N = 39$), and the average score was 84.86%. For the paired independent variables of Content Knowledge as measured by the NAEP assessment and Pedagogical Content Knowledge as measured by the Outcome Expectancies subscale of the STEBI-B on the dependent variable of Self-Efficacy for teaching science, the results of regression analysis were not significant ($F(21,2) = 1.73, p = .20$, adjusted $R^2 = .06$), indicating that performance on the NAEP as an indicator of science Content Knowledge and self-reported ratings of Outcome Expectancies as an indicator of Pedagogical Content Knowledge were not predictors of science teaching self-efficacy.

**Discussion of Findings**

The findings of this study appear to suggest that participants reported having average self-efficacy for teaching science, as the data for self-efficacy for teaching science ranged from a low of 26 to a high of 43, with the mean being equal to 32.81, yet from data collected during teacher interviews and the science education activity teacher journal, it would appear that teaching science was fused in practice with teaching reading and literacy skills. Due to this amalgamation of science and ELA, it is difficult to determine if the STEBI-B was an effective measure of science teaching self-efficacy in this study.

The subordination of science education in the primary grades may be one of prioritization. Accountability models in effect per the No Child Left Behind (NCLB) Act of 2002 placed higher priority on student achievement in ELA and
Math than in other subjects. The reauthorization of the Elementary and Secondary Education Act (ESEA) of 1965 with the Every Student Succeeds Act (ESSA) of 2015 maintained the annual assessment requirements of ELA and Math, and continued the triennial assessment model for Science in fifth, eighth and eleventh grades (Heitin, 2015). As such, primary grade teachers may have little incentive to engage in science education activities in lieu of ELA and Math activities, areas in which achievement may be reflected on teacher evaluations. The Executive Director of the STEM Education Coalition, James Brown, called the continued inclusion of Science in accountability models with the passage of the ESSA “a huge victory, because you could easily have seen science testing disappear” (Brown, as cited in Heitin, 2015).

These structural and political conditions suggest that science education will continue to be marginalized in the curriculum, as ELA and Math receive substantially more emphasis than Science in accountability models and resource allocation, including professional development (ESSA, 2015). With the advent of the Next Generation Science Standards (NGSS), standardized assessments aligned with these standards do not exist, but the ESSA included funding for science assessment development. Administration of an NGSS-aligned Science assessment is projected to occur in California during the 2018-2019 academic year (CDE, 2014b).

Based on the quantitative data, it does not appear that lack of content knowledge affected the amount of science education activities conducted by the primary grade teachers in this study. The participants in the study scored an average of 84.86% on the instrument constructed from released test questions from the 4th Grade NAEP for Science, which likely indicates possession of sufficient content knowledge for teaching science in the primary grades. Participants
reported completion of more Life Science courses than Physical Science. While the mean for both Life Science and Physical Science courses was two, 59.6% of respondents reported completing two life science courses, while 46.2% reported completion of two Physical Science courses, a difference of 13.4%. This disparity may be reflected in the types of science education activities conducted in participants’ classrooms. Data from interviews and the teacher science education activity journal appear to reflect significant emphasis on the study of life science over the physical sciences.

On both subscales of the STEBI-B, the Outcomes Expectancy (OE) subscale, which measures pedagogical content knowledge, and the Personal Science Teaching Efficacy (PSTE) Beliefs subscale, which measures self-efficacy for teaching science, participants rated themselves as average, scoring 3.88 on a 5-point Likert scale. However, when compared with qualitative data from interviews and the teacher science education activity journal, this level of self-efficacy for teaching science does not appear to translate into classroom experiences for students. A study conducted by Dorph, Shields, Tiffany-Morales, Hartry and McCaffrey (2011) in conjunction with WestEd and the Lawrence Hall of Science found that 80% of elementary school teachers spend an average of one hour per week teaching science. In the same study, nearly 20% reported not teaching science at all. Data from the science activity journal in this study appeared to support such a finding, while interview data appeared to suggest that while teachers profess to enjoy teaching science, the core of their science teaching practice is more closely aligned with ELA activities than with the best practices for science skills for which science educators have long advocated of “making observations and measurements of natural phenomena, articulating hypotheses, and designing and carrying out experiments” (NRC, 2007, p. 14). This may be
attributed to several variables, from accountability models to lack of training and resources.

In addition to strong focus on accountability and ELA activities, interview data suggests a lack of sufficient training in how to teach science both in teacher education programs and of in-service teachers. On the most recent Trends in International Mathematics and Science Study (TIMSS) (International Association for the Evaluation of Educational Achievement, 2015), the science achievement data of U.S. 4th and 8th graders remained essentially unchanged from 2007 levels. Nine of the 11 teachers interviewed stated that they had attended no science professional development, some over the course of a teaching career spanning more than two decades. Synthesizing best practices in the adult learning theories proposed by Knowles (1962, 1972, 1974) and van Driel et al. (2000), quality professional development should acknowledge prior knowledge and mastery experiences, be relevant in action research, and employ learning networks. The same tenets of adult learning theory that are present in the abundant professional learning opportunities that teachers are afforded in ELA and Math could be applied to science education professional development in order to increase student achievement and future participation and persistence rates.

In addition to professional development opportunities, all interview participants indicated that they did not feel that they possessed sufficient resources to improve their practice of teaching science, despite average self-ratings of science teaching self-efficacy. Time was identified by participants as a deficient resource, as were materials. Participants reported perceptions that other curricular subjects were a greater priority than science. Most teachers commented on a lack of materials or reported expenditures of personal funds to purchase materials to support units of study. Without investment in training teachers in how to teach
science and providing sufficient resources, improvement in science achievement is not a logical outcome regardless of how teachers rate themselves in self-efficacy for teaching science.

**Impact of Research**

The findings of this study could be used at several levels – collegiate institutions could use these data to modify teacher education programs to increase the readiness of teachers for teaching science effectively. Districts and individual schools could use these data to implement or improve professional development programs for primary teachers. The results indicate that teachers reported an average level of self-efficacy for teaching science, classroom practice is reflective of this level. From the qualitative data, reasons for this may include the absence of science in accountability models for primary grades, superficial knowledge of science content and pedagogy, time constraints and lack of resources. Several of these factors lie within the purview of schools to ameliorate by improved alignment of the implemented curriculum and the adopted curriculum, establishment of a more rigorous and better supported course of study in science education, and reallocation of resources to support increased frequency of science-specific professional development opportunities for teachers, and facilitate materials adoption. Such action would bring science education practices more in line with current executive initiatives to increase participation in STEM fields.

**Recommendations for Future Research**

This study examined the state of science education in two school districts in Central California, and was based on the continued national attention regarding the state of science education and its implications as the national economy evolves. Further research is warranted into the construct of self-efficacy for teaching
science in order to assist researchers in determining the specific actions that build self-efficacy for teaching science, and then how to best integrate those practices into pre-service and teacher education programs. Further, the results of this study seem to suggest that the majority of science education activities reported by participants were, at their core, ELA activities. Additional research may elucidate the reasons for the disparity between how teachers rate themselves for teaching science and how science education is implemented in the classroom. Further research into this contradiction may provide foci for professional development. Overall, it appeared that teachers have a positive attitude toward learning and teaching science, and are making valiant and creative attempts to incorporate some form of science education into their practice, but are constrained by accountability systems and resources, such as materials and time.

Another area for further study is the impact of accountability models for ELA and Math on other subjects. All interviewees commented on their perceptions regarding the impact of multiple levels of assessment in these subject on the remaining curricular areas. It may prove useful to use science education as a lens through which to examine how assessment drives, or perhaps dictates, curricula. Continued emphasis on achievement in ELA and Math at the expense of other subjects may decrease educational equity and violate the civil rights of English learners and socio-economically disadvantaged students. Further study of how state assessment schedules for science affect science teaching during the years in which the subject is not assessed may provide insight into programmatic coherence and make strides toward providing a guaranteed curriculum for all students.

While the quantitative data did not support findings of a relationship between science teaching self-efficacy, Content Knowledge and Pedagogical
Content Knowledge, qualitative data appeared to suggest that increased professional development in the areas of Content Knowledge and Pedagogical Content Knowledge to develop teacher self-efficacy for teaching science may be the high-leverage action that will result in intensification of science teaching in the primary grades, and increased student achievement in this area. Such growth in student achievement for science would do much to mitigate the future effects of too few workers in STEM fields, and possible resultant economic consequences. Research (Chambers, 1983; Potvin & Hasni, 2014) has suggested that students become disengaged with the field of science as early as kindergarten. Many of the current programs focus considerable resources on science education at the secondary and post-secondary levels, but by then, such efforts may be too little, too late. The time to start training the next generation of scientists is during their primary grade years.
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APPENDIX A: SAMPLE CONSENT LETTER

Dear Teacher,

You are invited to take part in important research regarding the important role that primary grade teachers have in encouraging achievement in STEM (Science, Technology, Engineering and Mathematics) fields. We are asking you to take part because your perceptions and experiences are invaluable to this study.

The purpose of this study is to ascertain how education policy may affect science education in the primary grades. If you agree to participate in this study, you will take two brief surveys. The first is comprised of released test questions from the 4th Grade National Assessment of Education Progress (NAEP) for Science. Participants in the pilot study completed this survey in about ten (10) minutes. The second survey is the Science Teacher Efficacy Beliefs Instrument (STEBI-B). It asks questions regarding the number of science courses completed and teacher beliefs about science education. It will take about ten (10) minutes.

Additionally, your participation in a follow-up interview and brief diary activity to provide further information on your teaching experiences and perceptions would greatly aid this study. If you would like to participate in the interview study, please provide your contact information on the line below. Optional follow up interviews can be as brief, or as in-depth as you would like, and will be recorded and transcribed. A small thank you gift will be provided to those who participate in interviews.

No risks are present in this study other than those encountered in day-to-day life. Your responses will remain confidential, and you will be identified only by the ticket number on the NAEP survey. Public reports will not include any identifiable information should you consent to be interviewed. Research records
will be kept in a locked file or password protected computer at all times; only the researchers will have access to the records. If we record the interview, we will delete the recording after it has been transcribed, which we anticipate will be within three months of its taping.

Taking part in this study is completely voluntary. If you decide not to take part it will not affect your current or future relationship with California State University, Fresno. If you decide to take part, you are free to withdraw at any time.

The researchers conducting this study are Kate Bays and Dr. James Mullooly. If you have any questions regarding this study you may contact Kate Bays at katebays@cusd.com. You can reach Dr. Mullooly at Jmullooly@csufresno.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) at 559-278-4468 or access their website http://www.fresnostate.edu/academics/humansubjects/irb/. You may print a copy of this form to keep for your records.

If you choose **NOT** to participate in this study, please provide your NAEP ticket number below and return this form to the researcher via Clovis Unified School District mail, Kate Bays at Lincoln Elementary. NAEP ticket #

______________________________________

In addition to participating in the surveys, I volunteer for a follow-up interview, and consent to have the interview recorded for transcription.

Your Name (printed) ___________ Email ___________ Date ___________

This consent form will be kept by the researcher for at least three years beyond the end of the study and was approved by the IRB on February 17, 2016.
APPENDIX B: QUALITATIVE LIMBS FROM INTERVIEWS

Assessment:

(Teacher #1)
Science has not been given to me as a priority. I’m dictated by what’s coming from above me and so I don’t have a huge amount of time in my day to do pure science education because the powers above me are not dictating my day that way. I have to meet those standards.
That’s the pressure that I’m under to have them do well on those assessments and those assessments are centered on Math and English Language Arts. When I’m observed, I have the state which Math or English Language Arts standard I’m using.
I’m aware of them [NGSS] but that’s not what’s in my day-to-day right now. I am faced with assessment after assessment. SBAC is next year and the pressure that I feel on me is more related to that. When I feel I’ve done a good job with those [tested] subjects and I can take a minute at the end of the day. Usually Tuesday and Thursdays I’ll bring in science.
SBAC test results.
…you get this big heavy textbook plopped down in front of you and have to read it and then answer questions on it, take a test on it. It’s enough to kill you.
I’m guided and I’m controlled, very highly controlled about what I’m supposed to be doing all day long. And I’m told what to do. I’m under a lot of pressure. We all are.
I wish it mattered more what we- I wish more people were asking us what we thought. I don’t feel like anyone’s asking.
I would be careful not to overemphasize the role of the teacher in this because I don’t feel, at least in the public school system, that as a teacher, we have this huge amount of control of our day. It’s very controlled for us...what everyone’s telling us to do. They’re telling us we have to meet his standard. Yes, because the school’s under pressure to do well on the SBAC so their scores look good. The SBAC is determined by someone higher than the school. The administration of the school feels pressured to score well and so that pressure gets transferred to us so suddenly we’re spending a lot of time trying to figure out what’s on the SBAC so we can teach that way.

(Teacher #3)
That why fourth grade teachers had the training – to help the fifth grade with their portion for the assessment quiz. We’re trying to kill two birds with one stone. We’re trying to teaching the reading standards which is what they’re being assessed on, with the common core and the SBAC and it’s heavy non-fiction text. I did a lot more experimental science in the fourth grade, because of the fifth grade test that came up. In the third grade it is not the tested curriculum. It’s not the tested curriculum. We just kind of went through what was going to be the most immediate standards to prepare them for the fifth-grade test. And that’s what we focused on. I think the reasons why it was a focus is because it was part of the tested curriculum. And that’s why it became a focus for the fourth and fifth. I can tell you, I have no memory of whatsoever if the sixth grade go the same training. I know the fourth and fifth did, because we went to the training together. But I can’t tell you if anybody else got the same training.
At that point, the science component of the CSTs hadn’t yet been fully implemented. We didn’t know exactly what the assessment piece was going to look like.
That is it not the tested curriculum, because if it was we would make those things important.

(Teacher #4) I know for some grades that are assessed in science, it becomes more of a discussion. For second grade, I would say science is a little more on the back burner…because what it boils down to is that second graders aren’t assessed on science.
We’re not taking state tests right now with the common, we used to in the past.
Even then, we wouldn’t have a science component for our state tests. Obviously we’re assessed in language arts and math. Continuously.
The district provides assessments, so we’re using area assessments. We have area teams that work on writing assessments. We have curriculum and instruction department for our district that provides us with all kinds of resources for language arts and math.
On our report card we an area we give them an effort grade. Second graders at our school are given an effort grade for both social studies and science.
I feel it is just as important to learn about science as it is to learn about all the other curriculum.
I think that just becomes, kind of leads to the inhibitors, which are more just things that are required, which are not science-related. Like the weight of the other subjects in the other curricular areas, the emphasis that’s put on other things and things that we’re required to score and assess.
I think maybe ten years ago or something, the writing along with the science might have been more fluff for a second grader, might have been more, oh yeah, go write about it in your journal, but it may not have had as much weight to it. Maybe it was graded, maybe it wasn’t, maybe they weren’t held as accountable for some of those parts of science, because I think it was more in isolation. I think now, we’re finding a lot more that it’s easy to hold them accountable across the different areas of our curriculum for science activities.

You might occasionally seek an article or something in some of those assessments that again, could be related to one of our standards like a life cycle or something like that, a reading article, but not assessed on any of the understanding of science standards.

It’s not even a graded area.

We’re assessing kids a lot. We’re assessing kids a lot for new ways, which I think is taking a lot of time. We’re assessing a lot of kids not in science, but in a lot of various where you sometimes have to give time-wise. Second graders take a while to do things, and when they’re given so much that is a requirement that has to be done, an assessment that has to be turned in, I think what’s happening now is that we’re taking a lot of that time.

We’re assessed on language arts and math constantly. I’d pretty much like kids to be able to just show what they know, and I’m pretty happy with that. If I can get that, I’m happy regardless of the outcome. Maybe that’s not the most politically correct thing to say, but that’s how I feel as an educator. I think that sometimes when you know something else, another assessment’s coming for language arts of math, and you know, okay, do we review this or do we do that?
…integrate science into other things we do. If you’re not doing that, for example, in a second grade classroom now, when you are assessed in different areas, it’s going to be hard for you to do it.

(Teacher #5) We have to meet a certain, what would you say, percentage of mastery. Some kids have it harder to be able to get to that mastery and I think as teachers we have to hit, which is impossible, 100%. Recently I had a discussion with a kindergarten teacher. She said that they have to hit at least 100% mastery in their skills and that they at least 25-30 masteries and if they don’t hit that, they receive a negative assessment.

Yeah, their evaluation.

I think it’s coming from the top and I think it’s, and I hate to say this but I think it’s partially because of the common core, because everybody is trying to hit that mastery. It’s not realistic.

…the teacher’s success depends on how the students’ outcome is. I remember when I first started teaching, 90% was what our goal was. Talking to the kindergarten teacher, she goes ‘I have to get at least 98% or 99%.’ So if that student doesn’t get to that she says I go back and I reteach the same skill again and again and again.

I think it’s just pressure for teachers to get the assessments done. I mean there’s a lot of testing that we do on the computer, paper and pencil testing, and then of course our regular testing from textbooks.

It’s leading our education. It’s leading how teachers’ lessons go. This is where I have to get to and I’ve only got so many hours in a day. I have to do this.
(Teacher #6) I meant formally where things are assessed and that I’ll throw some things in here or there. Which are more activities or journal writing and things like that, not so much that they’re going to come away with an understanding. We’ve done maybe 6, maybe I’ve done 6 or 8 weeks of science. Because it’s not on the state tests. I think that testing drives instruction.

(Teacher #7) It’s very easy to get into the task-oriented where they need to learn these specific things, and are assessed on these very specific things. Another thing we’ve done, and this tough, but with assessments, and we assess all the time, and it’s every week that we commonly have been assessing. This year we’ve kind of done it every other week we assess that way on Friday, which is usually just assessment day can be spent doing that. My perception of it comes with the stress of testing on certain things. Science for third grade is not directly like…Well, it is and it isn’t. I know that science would hit a lot of…science reading and informational reading would definitely hit a lot of what they’re covering…but I think there’s kind of this fear that we really need to focus on ELA and math. That data for our kids is going to be shown to everybody, and we don’t want to be embarrassed. Because I think that adds to the stress to where we feel more confined to what we can teach because it’s what we should teach because that’s what we are being assessed on, because they’re being assessed on. There’s claims that the data is not used in that way, but it definitely is. There’s always talk about scores, if they’re high or they’re low. There’s congratulations if they’re high, and if they’re low, you know, kind of what happened? Or explain what was going on when…
At the beginning of the year, it’s like “Oh, don’t worry about it. We’re not going to be looking at that this year,’ and then the next year, it’s like, first time we come back to together after summer, it’s like, ‘So and so did so well. Let’s all give him a round of applause.’ It make you want to get the kudos for teaching that things that are being assessed well. It limits a desire to spend more of that time on the good stuff, you know?

What I think our drastic change is – and I think Teacher #8 would probably disagree – but we would test hundreds of questions every Friday. Every Friday would be all-day testing. We test almost more than most other grade levels for what age they are.

We’ve been testing less. Like, fewer questions, and sometimes every other week. For me, that’s a huge change. For her (Teacher #8) coming from fewer assessments, you know, how often you assessed at your previous school site to infinitely more, it seems. It’s just drowning in assessment. For me, it’s like, I can breathe. For her (Teacher #8), it’s just like, submerging under the weight of all that testing.

It’s not tested. I feel a little bit of an inhibitor. It helps me focus on things that are not quote-unquote science.

People just not being, I guess, as passionate about it as they are about their kid succeeding on test scores, or whatever it is.

Because I want to be successful, I mean, I want to be a good teacher, and have successful students, but the way we measure success if not necessarily…You know, it’s harder to assess their enjoyment of this activity. I mean, you can assess it, but it’s harder to assess and put data up of how well they did…versus, like, paper and pencil rated percentage test.
(Teacher #9) We’re overwhelmed with reading and math. And writing. Those are areas that we are seriously tested on, and those are the areas I focus on a lot.

Literacy/Language Arts and Science Misalignment

(Teacher #1)
I don’t think pen and paper and textbook would be nearly enough, so it would have to use technology and hands on experiments, note taking, group work in order for it to be a true science education.
I was given a binder of ELA standards. Everyone who’s ever talked to be about what I’m doing in my classroom, it’s all been centered on those two binders.
I have to state which English Language Arts standard I’m using.
As a second grade teacher, people really don’t say much about science. It’s all English Language Arts and math.
The science we’ve done this year has been mostly about the study of animals and it’s all integrated with writing. We did a lot of informative writing all winter really. We would study an animal, read about an animal, watch videos on that animal and then write an organized paragraph or two on that animal.
Right now they’re doing research on penguins and they’re actually making their own penguin book. That’s what we’re doing in science right now, but it’s also our writing.
It’s pretty heavily science-oriented but on a lesson plan it would be written out as writing standard. Also close reading is this big thing right now. A lot of it’s non-fiction and so it does hit science topics. We’re doing the ELA close reading standards on science topics but that’s a very one-dimensional way to learn science.
Certainly reading the close reading or only reading about it and writing about it is not enough.

The point is to do more close reading. It just happens that a lot of those topics are science related so a lot of it’s non-fiction.

…you get this big heavy textbook plopped down in front of you and have to read it and then answer questions on it, take a test on it. It’s enough to kill you.

When science becomes just another big heavy textbook that you have to open up and read, choral read or listen. Take turns while your friends read and you’re just sitting there? That’s really boring. I don’t care what the topic is, you’re going to be bored.

My priority, I have spent a lot of my own money but it’s mostly on books because even more important than science is I’ve got to get them reading.

My list of priorities it’s been on books over anything else. I’ve invested in books. However, if we can’t get them on grade level or above in reading and math, then it won’t matter. Science won’t matter so much if they don’t have the basic academic skills.

You almost have to put it all into reading and math because they’re coming at your further away in many cases.

If there’s not as much emphasis on reading at home or books at home then they’re coming at you maybe further away from that than kids from other backgrounds. It won’t help them in science if I can’t get them to be good readers. That has to be my priority.

We’ve done a lot of animal research and I do use technology in terms of science documentaries and videos. Right now we spend a half an hour doing our penguin research in writing and then I put on a penguin documentaries for another 15 minutes.
Unless you consider looking in a lot of books, I haven’t done all that much. I would rather buy reading books with that money because I can use them year after year after year. They’re telling us to do a close read and then they’re telling us that our kids need to read for 60 minutes every day.

(Teacher #2) …being able to talk about what they observed. You can’t just read about it. It’s a good pathway to a lot of different curriculum areas…they’re writing about what they’re seeing and touching, they’re able to connect it to some texts that we’re able to pull into it. If we have a good story that moves into another area, we will connect a science lesson to it.

[District curricular priorities] Reading/English Language Arts. Based on the trainings that I have been offered that it goes; reading/language arts, then math. We have been reading some folk tales here and there, some Native American tales, the folklore tales and they understand that the folklore tales were developed because they didn’t’ have the same scientific knowledge vase that we have and they will make those connections. Yes, and I have attended many ELA, many math and many technology seminars… If you are spending ninety percent of you day in English/Language Arts, you only gave ten percent of your day to those kids who need the science a lot more. …those kids who are the verbal-linguistic, it is the way to challenge their minds and get a new vocabulary or a new skill set going for them.
That in teaching vocabulary, those enriching experiences aren’t always present at home.
It ties in really well with our close reading emphasis that we’re doing in ELA right now.
Things that I do here are interconnected…So, we did a close reading on sloths, we wrote a report about sloths
You have your small groups in the office in the afternoon and I have definitely pulled my small reading groups and done non-fiction texts with them that connect with what we are doing in science.

(Teacher #3) There have to be lessons, vocabulary…ELA lessons, so vocabulary building, reading. Reading comprehension is embedded within the science education for the third grade. They have to have that background knowledge, so we use a lot of non-fiction text to do that, so we can go into the application portion or research portion or the experimental portion of our science unit that we’ve developed.
For us, it takes a long time to teach those standards, because we’re integrated within our English/Language Arts block. We don’t teach them in isolation, we’re teaching them together.
We do a lot of research based. A lot of kids researching items….a lot of it is just research based. So the kids have a topic and they are navigating through already designated sites where they’re only allowed to go. And they’re learning information and usually creating some type of project based on their research, whether it’s an actual research item or it it’s…Most recently, they’ve created an actual trifold. They also created learning posters, where they presented kind of like a jigsaw, where we jigsawed some units and then they created…They had to
be the experts and they had to do their presentation to incorporate their listening and speaking standards, which are part of the ELA standards. Those are the types of products they’re creating, so it’s a lot of us using that content of science embedded within our English/Language Arts blocks.

So, it’s a lot more reading, writing, and producing some type of a project based item to show… So instead of an assessment, their culminating project would be that we would grade them on.

We’re trying to teach the reading standards, which is what they’re being assessed on, with a common core and the SBAC and it’s heavy non-fiction text.

We have science books, yes, we do.

[Curricular priorities] I would say English/Language Arts, Math, then Science. In that order. Everything that composes English/Language Arts.

Research. Research. They will tell you it’s a lot of reading, there’s a lot of writing. There’s always a research and there’s always a fun project at the end…It’s research based science. That’s how it is.

So, though we feel that it’s important to teach it just like we also teach Social Science, we tend to integrate it within our English/Language Arts, so we can fulfill both components.

You have to be a writer, you have to be a reader, and you do have to be a consumer of the information to process what you’re looking at. So, it’s good that we’re doing that component of it, because sometimes kids think science is just building a volcano or like what they see on television. And it’s more than that. It’s research….our shift was more to the other end as far as like researching and that. There is going to be a lot of that in science that kids have to understand that that’s part of science whether you’re reading research in science or research in
social science. They mirror each other in the research process, so the kids need to understand that reading and writing are so important to be a good scientist.

(Teacher #4)
I think for second grade in particular, we’ve seen with a lot of our reading assessments and things like that they’re going to more non-fiction.
I think before, we would have a lot of maybe more towards language and thematic teaching that second grade teachers have done for a long time.
That we’re seeing in lessons that are preparing second graders for common core is a lot more to do really with our ELA standards, not necessarily science standards.
What we’re seeing is just that the rigor of the articles and things that they want the kids to be able to read has increased, and a lot of the examples and a lot of the resources that we’re getting and that we’re finding have a lot of science in them.
Science was, I think, taught more solely in that where you might refer to something in a book you’re reading or something like that.
We’re also incorporating more of our, again, tying it into our ELA because ELA is such a big focus for us…The kids are going to be journaling…
Yeah, we’re definitely doing a lot of reading. We’re using it for writing, so we have to write, obviously read and write all the time. We’re trying to find science articles and things that are aligned with our standards, but yet at the rigor and at the right reading levels that we need to make it also enhance our ELA curriculum, and then that does along with the writing too. I think maybe ten years ago or something, the writing along with science might have been more fluff for a second grader, might have been, oh, yeah, go write in your journal, but it did not have as much weight to it. Maybe it wasn’t graded, maybe it wasn’t, maybe they weren’t held as accountable for some of those parts of science, because I think it was more
in isolation. I think now, we’re finding a lot more that it’s easy to hold them accountable across the different areas of our curriculum for science activities. You might occasionally seek an article or something in some of those assessments that again, could be related to one of our standards like a life cycle or something like that, a reading article, but not assessed on any of the understanding of science standards.

We have curriculum and instruction department for our district that provides us with all kinds of resources for language arts… If it’s something that doesn’t use that [science] book at all, or if it’s an article, or if we’re doing something that might be considered a close read, but it’s a science topic…I point it out to them, I don’t know, maybe because it’s not the book. Obviously I want second graders to be able to read. I want second graders to be able to write. I want them to develop all those skills, but because you can’t incorporate science and the science topics into that, I think it is just as important. If you’re trying to do it just in isolation and just take out your science book in isolation and go through that science chapter and get all the other things done, it’s not going to work as well.

(Teacher #5)
Non-fiction information about environment…basically non-fiction text and it causes children to think out of the box… We talk about light energy and we do talk about the planets a little bit. Recently we’ve been really integrating the biomes to talk about environmental studies and to talk about how the animals adapt and what adaptations they have had to have. Reading and discussion and for them to do fact finding.
Research, yeah. Then I try to integrate that into a research project and usually some form of art involved with it. This year we’re also adding Google classroom. They have a framework to type their presentation into...then to talk about it and educate the class.

[Curricular priorities] I think it’s more on non-fiction facts, reading, for children to be able to recite or summarize what they’ve read and then be able to try to compare and contrast the facts that they’ve learned with another type of fact.

Reading and language arts, and of course, math. With math, I think we’re trying to integrate more of their reading skills that they’re learning, the close reading for them to be able to apply their reading skills...have the children be able to apply their knowledge with the non-fiction information to their learning.

A lot of times, I don’t think they apply their reading skills that they’re learning as they’re reading. When they’re reading a story, they see it as a summary of a story. Now they’re realizing that the facts that they’re learning, they can put into a bullet and the have to write a paragraph. I think that’s the foundation we’re laying in third grade, it’s kind of like the foundation we’re laying. I think in fourth grade, they’ll really see how what they’ve learned in close reading can be applied across their grade levels.

It’s more pushed towards non-fiction information, and for us, for the science part, we are talking about biomes, which is what we’re supposed to be talking about. I think we’re more into the ELA standard and pushing that into science so that they have the basic reading fundamentals and hoping they’re applying that to their science non-fiction reading.

What I’ve taught in science has been basically from the textbook. So I really push like when we have something in *Time for Kids*, for them to really look at how the
information is displayed, how the text is used, how the pictures are there with the
information from the text and how they integrate it with a different data collection.
When we’ve had debates I’ve told them you have to have the facts to be able to
substantiate your own opinion. So we’ve done some debates in class, not
scientific ones, though. They’ve done more debates on things that are more key to
them, like dress code or about cell phone use, things like that, but not on scientific
ones.
We’re being put into a situation where we have to teach ELA.
Such as, if it’s science that they really like, they’ll learn to read…I think we have
to pique students’ interest levels. Then I think that foundational skill will start
increasing. I think some of the materials we use aren’t interesting to the kids.
They did the research. They went to the library. They went to the internet.

(Teacher #6)
We’re teaching reading through science. We’re still learning how to read, we’re
reading non-fiction. In third grade, we’re still teaching reading but we use science
as a tool. They’re already engaged and it’s just half the battle right there in
teaching reading.
I don’t know, I felt like using just the textbook was not the best way to teach
science. It’s one tool, but it’s not the best way. I don’t know, we work together,
third grade, and so we haven’t been doing as much as I think we all like to.
Because we’ve been sticking with textbooks.
Usually just hands-on, sometimes journal writing, recording observations. Trying
to incorporate things like graphs but not always and trying to get them prepared to
do a science project. Sometimes we try to do things that are close, not exactly,
with all of the research involved, but we will try to do the scientific method a little
bit. We have a journal, we have a science journal, and I let them just do their own observations and they do illustration and we try to throw in as much math and things that we can.

[Curricular priorities] I that that science has not been, I think it’s all been ELA and not talking about it. They are saying more non-fiction but our science curriculum I think is lacking.

Because for third grade, that’s what can, you can be retained for ELA but not necessarily for math.

They could be doing a cold read or something that a science topic and they don’t know it’s science.

They do have their science book out…When they get rid of the ELA book and put in the science they like that…

…they learn by doing. Not just be reading.

Mainly a tool to still teach comprehension, to teach ELA is still the focus and I do think it’s on the back burner with all the other subjects.

…the ELA focus. Probably a big chunk of our mornings, a couple hours.

Science textbook and report writing

(Teacher #7)

...being able to turn that data into information that they use to further study whatever interests that they have.

Specific vocabulary…before we learn certain content, given them opportunities in their groups or in pairs to ask each other questions, and talk about what they think, and what they’d want to learn, like the K-W-L chart. What you know, what you want to know about, and then I’m giving them opportunities to find out some of
that information through research and reading, asking questions, or having dialogue with other students.

…conversation, more questions, there’s more dialogue between students, and between class and teacher, and digging for answers more so than reading a story. I think what we go to is the textbook or technology. I know that we’ve gone to making stuff on Google Drive where it’s a set of... Like if we’d been learning about land forms, different like to different websites to learn about different land forms, to watch little videos on it, or, you know, songs and things of that sort, and then going through some of the textbook and looking at some of the different land forms. I know we created a little booklet.

…they have textbooks, and we can all read…the discussion side is usually pretty good. There’s a lot more questions with this type of content, but it’s not going to be something they’ll remember when they’re in high school. Like, ‘Oh, I remember when we read through chapter six. How great. We got to read it twice.’

It needs to be done, not just read.

[Curricular priorities] Math and ELA. We have teams working on…Our C&I is working on…We have those two teams…There was, like, a person for K through 6 or something that was trying to help innovate technology into that, but it was definitely ELA/Math.

…I mean, we read with it, and we do our writing through it, and there’s a lot of math, reading different…it depends on the topic, but just reading different charts or graphs.

We were doing fables and poetry, and fictional writing, we didn’t focus at all on science. We had none on that.

It’s like we have an ELA test and we have a math test.
Science reading and informational reading would definitely hit a lot of what they’re covering – and we’ve been doing a lot more informative writing and non-fiction reading for our close reading and stuff, but I think there’s this fear that we really need to focus on ELA and math.

Reading a story to someone, and discussing the elements of the story seems much easier than discussing a topic where there can be lots of questions that are hard for us to answer or we can’t answer.

It wasn’t the lectures. I don’t remember any of those lecture days, or opening the book, and the pages that I was reading. It was all about the things we did.

…sometimes we’re just given all these standards to read and dissect…

(Teacher #8)

Not just like, ‘Read the book and study the vocabulary words’ like some other science teachers do…

Reading and discussion.

[Curricular priorities] ELA, then math, I would say, if I had to put them those two categories. Writing.

…I think they would say something along the lines of they get to research and discover things. I think he [a student] would related it to getting to do some research and discovery.

I think it’s like, the kids are just going through the motions type of thing with normal ELA stuff that we do every day.

Like if we have a narrative story, maybe spending 2 weeks on that time so we can find an informational piece to do with that so the kids can see that we can do more than just one thing with this type of thing.
We’re competent in teaching ELA because we’ve been to the trainings and we kind of know what to do.

(Teacher #9)
Yes, definitely, what the kids can touch and feel and see themselves is a whole lot better learning experience that reading about it in a book, and by the way, we don’t have science books. So we’re not reading about science activities in books. We have non-fiction books that talk about scientific things that we might read in a guided reading group…Actually into teaching them how to read. …it’s exploration through books and through reading sources.

We’re overwhelmed with reading and math. And writing. Those are the areas that we are seriously tested on, and those are the areas I focus on a lot. And I’m not saying that I couldn’t integrate it all but I do get bogged down with just the aspect of teaching reading.

I’m teaching reading in small group, that’s when I feel most effective as a teacher, and sometimes we are reading science books, the little readers that have to do with science…

This time of year, they can write down stuff. At the beginning of the year, they can’t write full sentences.

We do a lot of ELA centers…Listening center, it could be a scientific book at a listening center.

[Curricular priorities] Reading and math. Are reading and writing and math. …better communicators. We’re trying to teach them how to communicate and tell each other how they got their answers and validate and justify, and honestly, they have a hard time just forming a sentence sometimes. But if they were talking
about simple scientific facts the, because it’s so high interest, maybe they could
draw pictures and then explain it to their neighbor.
Better thinkers, better communicators…Communication is such a huge thing right
now, and we’re struggling in first grade to get these kids to talk about their
learning and their thinking.
I’m a very strong reading teacher, not so strong math.

(Teacher #10)
I mean, it’s the reading and the research and experiments.
That is, we use reading to do reading and we’re using the subject of science for
these kids, which kids of gives them a little bit more eye-opening of their world
around them. It’s more focused on reading than it is really the science, I mean, the
science experiment’s behind it, but it’s more literature based.
I’m giving them reading passages. They’re taking notes from those passages and
then they’re taking those notes and putting it in writing. There’s a lot of writing,
and of course, reading and writing go hand in hand. There’s a lot of reading and
writing involved and you know, there’s comprehension as well, looking for those
reading answers and process in that as well. We also use them for reading groups,
get them to use some strategies that we have taught them in reading to be able to
find unknown words with the use of non-fiction books, which is primarily animals.
Everything centers around reading and writing…I know it’s not as effective, but
we do do peer share. They are talking about it, they are doing art projects so it
helps, you know, helps them visualize what they are learning about, which I think
is important for the primary grades. It’s the art aspect of science, but it’s primarily
around reading and writing because that’s the foundation that we are trying to
establish for the later grades.
Would you include writing as a hands-on activity?
Just, you know, it’s all about reading, writing and math. Classroom setup is more about seatwork or collaboration with one another. Yeah. Or reading in small groups.

[Curricular priorities] Yeah, reading, writing and math.
My hands are tied when it comes to reading and writing, that’s the foundation that we really need to establish in first grade. For them to be successful in the later grades so that they can read for the later grades…
It gets them thinking about things and being critical thinkers…Science activities, I think it is important but, without reading and writing because that’s where we so focused on in first grade. How can they do some of that stuff without being able to read instructions and listening skills because that’s also important in first grade. Because if they don’t have that foundation here, it’s kind of hard to make up ground when it comes to that. Without reading and writing, they need to be able to read the instructions for those activities and listen on how to do those activities and how to participate and be, to all those things.
I have to teach them how to read, I have to teach them how to write…there’s a lot more vocabulary that they want us to teach…there’s a lot more collaboration with all the reading and writing and math.
…you have to teach first graders how to be collaborative and how to talk and not mess around. To remain focused even though it is a louder environment and they’re going off in separate directions as a group.
To a certain degree, like I said, I’m primarily focusing on the reading, writing and math.
(Teacher #11)
I know that the science standards are online, but no one’s, like last year when we went to our workshops for reading, they basically focused on reading and the math, but the science not so much anymore, so that’s why we’re still using our old standards…
…even the teacher education program, it was more focused on reading, teaching children how to read and then math. Lots of math and lots of reading.
Most of it is, we use our science book and then we do research. We do a lot of research using the books, library books…Most of it is research and then using our science books.
We answer questions and then we write about the research. We end up with projects. End up with projects is the end result.
[Curricular priorities] I think reading and math, mostly. That’s what I get the feeling of, so I think it’s reading and math.
…what I’ve done is they have a little journal that they keep and so they do their observation and they write about it and then we’re also writing. I’m reading them books on the silkworm and they’re writing, they’re going to end up with a paper on silkworms is what they’re going to do…It’s very thematic.
…my focus has been a lot on reading and reading comprehension because of the grade level that I teach and have taught.
…a lot of workshops and most of them have been in reading and math.
Mostly it’s reading out of the book, answering questions, or doing research because we’re working on a project or something. I do a lot of Bill Nye, the Science Guy so sometimes when I’m teaching, because we use our Wonders book that goes along with our reader and I like that a lot, and so what I do is I preview
what I’m going to be teaching.

Professional Development

(Teacher #1)
…I was given a binder of ELA standards and a binder of Math standards. Everyone that’s ever talked to me about what I’m doing in my classroom, it’s all been centered on those two binders. Science has not been given to me as a priority. Even if it were my personal priority, I’m dictated by what’s coming from above me, so I don’t have a huge amount of time in my day to do pure science education because the powers above me are not dictating my day that way. I did go to some outdoor science camp professional developments…was a long time ago, but of course what I learned there I can’t realistically really do. I could theoretically. We could go on nature walks and stuff like that around the school, but it’s hardly realistic.

(Teacher #2)
I am talking about the one you would actually find on the California state website. When you type in ‘First grade science,’ the ones that you would pull up straight off their website. So, it is the California Common Core Science Standards. We haven’t really talked about the Next Generation Science Standards yet. Yes, [six years ago] in my previous district we attended…it was through XCOE. It was just a little seminar talking about different ways that you can incorporate physical science into your classroom. I think that was the only one. Yes, and I have attended many ELA, many math and many technology seminars and conferences after that, but that was my only science [one].
(Teacher #3)

What prepared me for that was the second or third year teaching. Our principal signed us up, signed us up for AIMS. And we went through an intensive semester. Professional development. We went to sites, whether it was the Pacific University I don’t remember exactly where...It must have been Xxxxxx Unified somewhere. And that’s where they showed me how to teach science in the fourth-grade classroom. So we had purchased the aides, the binders, the curriculum... We didn’t purchase all the supplemental items, like the things you would need to create and experiment. We just kind of went through what was going to be the most immediate standards to prepare them for the fifth-grade test. And that’s what we focused on. It helped us to develop a conceptual idea of how to integrate it, so we used a portion of what the district had, as far as a textbook and then created what AIMS had and integrated that. That was, when I first started teaching. That’s why fourth grade teachers had the training – to help the fifth grade with their portion of the assessment quiz.

The Science Standards we’re teaching to? We are in flux because we’re changing from what used to be there to the next generation standards. Right now, we didn’t realize it until after we were done, we taught the Earth Science unit with solar systems, planets, which is no longer ours. What is ours is biomes, the adaptations, the environmental science, the life science, which is the major component of the Next Generation.

Not recently. Not since I was first a teacher. Like I said, we did the AIMS training when I first started and I taught at another school. We got that. And then, very minimal. It’s declined as I moved from upper grade to primary, because if
anyone’s going to get science PD, it’s not going to be the third grade, it would be the fourth or fifth grade.

Yes, it was AIMS, yes. It was AIMS workshops and we AIMS binders that went with them. There was one binder per strand, so there was Life Science, Physical Science, and Earth Science, and there is Experimental…binder of who to do the experiments within the classroom. There’s also a total of four binders and we shared them as a grade level. And it went with the actual professional development that we did. But that was the last time I received science professional development.

The difference was that I was in a different grade level. I don’t think I would have received that training if I had been a third grade teacher at that point. I think the reason why it was a focus was because it was part of the tested curriculum. And that’s why it became a focus for fourth and fifth. I can tell you, I have no memory of whatsoever if the sixth grade got the same training. I know the fourth and fifth did, because we went to the training together. But I can’t tell you if anybody else got the same training.

At that point, the science component of the CSTs hadn’t yet been fully implemented. We didn’t know exactly what the assessment piece was going to look like. We just knew we didn’t have the resources. We didn’t have the training. And the know-how to even get started. That’s why we started with AIMS. Soon after that, I left that school site. I stayed in upper grade, so I continued to use what I knew. And that principal didn’t purchase the training, but purchased the binders. And you didn’t need to be trained again, which makes sense. I continued to use that until I changed to primary.

[How did you learn about the NCSS?] Well, it’s a little naïve, I guess. I just assumed that everybody had to know that. We’re teachers. We just had
discussions about it in our PLCs. I am also part of a learning cohort, so we talk about it in our learning cohort as well. So, we talked about it among each other, collegically [sic]. We’re collegically [sic] talking about it within our PLCs. And the fact that every time we’re sitting down to plan a year or whatever it is that we’re going to plan, someone’s always in our team on the internet looking at something. So, just by teachers researching we have found out about the Next Generation.

No, there has not been any in-service or any professional development specifically around the Next Generation Science Standards. We know they’re there, while they know that we’re fully implementing them next year. That’s not a secret. Our administrator has told us that, but as far as receiving training or understanding the standards – no, nothing has been done.

(Teacher #4)

What we’re seeing in lessons that are preparing second graders for common core is a lot more to do with really our ELA standards, not necessarily science standards. Science standards have stayed the same.

I am offered professional development activities all the time. I can’t remember being offered a science professional development activity ever…I may have been offered a science camp one time when I first started teaching as well. I take that back, but it’s been very few and far between, because I’ve been offered so many other, I’m always offered professional development opportunities.

(Teacher #5)

No, none. What I’ve taught in science has been basically from the textbook. When I need more facts I’ll go onto the internet and find things. I’ll use Brain Pop because that’s really good. It’s right at the students’ level, or YouTube
information. *Time for Kids,* we use that a lot because I like it because it includes a lot of science information and facts.

(Teacher #6)

…we were a little bit in limbo for a while. We knew that they science standards hadn’t changed but, yet, we didn’t follow along as closely as we used to. Even years ago when we would do AIMS activities. Did you ever do AIMS? One year when I taught fifth grade in Los Alamitos…we went to outdoor science camp and that was a blast. I think it’s similar to Sonora but they called it outdoor science school and it was a lot of fun. …But I have not been to many things for science. Other than something that I see or hear on my own for find out. …no, I really don’t have a lot of formal science professional development. Yeah, something like that. I actually almost went to one at the RAFT, but I just couldn’t make it to the Bay Area that weekend. On the new generation.

(Resource Area for Teachers)

But, no, there really haven’t been a lot of things. It used to be but even this, for all of even language arts and math. There are not as many things that come around one emails about, there’s a workshop, we have money, do you want to go? I don’t even know what the new ones [NGSS] will be and even the old ones, sometimes we would stick to them. But if there was something we loved doing we would do it anyway. If it was not a third grade standard and I think that that happens district-wide, too, a little bit.

(Teacher #7)

Aware is the appropriate word, yes. We have not gone into as much detail. We had signed up for training where we thought at least an overview was going to go
over what the next generation ones would be, nothing was. We’re hoping that during this summer or sometime we can really go into those as deeply as we’ve been shown or taught to do with the ELA and math standards that have been rolled out so far.

It’s not something that was necessarily publicized. I knew the guy who works at Xxxxx County Office of Education, and we happened to be going snowboarding, and I talked to him about the science standard. He said, ‘Hey, we’re doing this workshop in a month. You should check it out.’, and then he sent me an email. It was very…It just kind of fell into my lap. It wasn’t something where it was highly publicized. Maybe I had missed other emails or something about it, but it was nice to be able to talk to somebody, and them encouraging that. It was very easy for administration to approve. I just hadn’t really, I guess, pursued it enough on my own. [Other than that] None. I want to say none.

Yeah, I agree. It tough with just the training. We’ve been to so many trainings where it’s like, ‘Hey, that’s a good idea,’ and do nothing. Then there is sometimes where it has be a combination of, I think, both of them. It was really nice to go to that training, get the hands-on experience, get excited about it, and then encourage each other, and help each other to make it happen.

(Teacher #8)

Yes, he [Teacher #7] found one and we asked our administration, and they set it up for us and got us to go last month.

[Other than that] I want to say none, too.

I did lots of professional development with my other school. Science was mentioned, but it was never a focus on science. They would mention the new standards, and things like that, but never, like, ‘This is a science workshop,’ or whatever.
I think what helped start it, even going one step further back, was the training that we went to. Because then we felt confident in doing this, too, because we’re more confident in math because we’ve been to the math training…Science not so much. Less confident in, then this training helped boost our confidence and say ‘Oh, that was fun. We actually did some of those activities. I think our kids would love this,’ and that’s what sparked it, then the fact that we had each other too, to plan it and do it.

(Teacher #9)

No, the best that I remember was way, way back is in Xxxxx, being trained in some AIMS lessons, do you remember AIMS? …But way back, I remember using some AIMS activities. I remember using it with first grade, but my first experience was teaching fifth grade.

Straight, no. Have I, or have I had the opportunity? No, I have not gone to any. Have I had the opportunity in the 25 years I’ve been teaching? I don’t remember. Maybe that could have been some PD. I don’t remember. Can you think of some in the like last five years?

Right, I don’t think I’ve ever been to one. …Maybe if we asked, maybe the district would come up with some money to send us to something. They would have to be, you know, something I would research and say, ‘Hey, I want to go to this.’ But admin’s not showing us, saying, ‘Hey, I want you to go to this, look at this.’ You know, they’re not promoting it, I don’t think.

Yeah, just having this conversation now is actually motivating me to think about how I can fit this into my schedule better. I haven’t had a conversation like this in years. It’s, we don’t talk about it at staff development, we don’t ever talk about it, we don’t talk about it in our PLC, but all this stuff I’m trying to get my kids to do
could be grounded in a science framework, you know? All the thinking and communicating and all that could be around something high engagement. Yeah, I feel motivated to get out there and look for some resources.

[Are you aware of the NGSS?] No. You’re talking to a total rookie. I don’t know any of that. Is this separate from the common core standards? What is Next Generation Science Standards?

How about some training? It would be really nice for this district to bring in some training. Put us through training. I’m, I’m in a three year math cohort, which I feel like I’m learning a lot, I’m a very strong reading teacher, not so strong math. Well, maybe after that I’ll go into some science training if they offered it.

(Teacher #10)

One. About our new curriculum. That was seven years ago. I think they were working in conjunction [with the publisher] and we all thought, when do we have time to do all this?

(Teacher #11)

Right now, we’re teaching the old science standards because I don’t have the new science standards. They haven’t given us the new science standards. I heard that they were posted but I haven’t had the chance to go look at them, so I’m just using our old science standards and so all the material that we’ve gathered for that then that’s what I’m using right now.

I’m not aware of it. I know that the science standards are online, but no one’s, like last year when we went to our workshops for reading, they basically focused on reading and the math, but the science not so much anymore, so that’s why we’re still using our old standards, so I wasn’t aware of that.
No. It’s not that I have not had the opportunity. The opportunity may have come up and I just chose not to take advantage of it because my focus has been a lot on reading and reading comprehension because of the grade levels that I teach and have taught.

Not that I can think of. I’ve attended a lot of, a lot of workshops and most of them have been in reading and math. I don’t remember really attending a science workshop, to be honest with you.

I know they’re online and all that but they haven’t really come out and told us what the science standards are yet for third grade.

I think maybe if they had workshops available to attend. Yeah, I would go. I would do that, but I want a good one. I don’t want one where they start…I’m a visual person, so I need to be, ‘Okay, this is the way you do this. This is how you teach this.’ Give me examples, especially with science and stuff like that. A more interesting way of teaching something. I know that hands-on and I do the videos and do all that, but it there something more out there kind of thing. I’d be open to that. Absolutely.

Undergraduate Preparation

(Teacher #1)

I wouldn’t say that it directly focused on that specifically.

(Teacher #2)

My undergrad degree is in English, so we read a lot of scientific texts, but I don’t know that it was necessarily preparing me for that…I originally intended to teach
middle or high school English. I went through and that’s just my passion anyways, literature. I went through and got my undergrad in English with a concentration on American literature and then started substitute teaching and discovered that I actually preferred teaching in the younger grades.

(Teacher #3)
It didn’t. I don’t think it really did. Gosh, it was many years ago. 20 years ago, I just remember taking one…I took my science content to graduate, to get my undergraduate bachelor’s degree, but as far as how to teach and how to integrate science into my everyday curriculum, it was one class and I don’t feel it prepared me at all.

(Teacher #4)
…my bachelor’s degree was in psychology, so that may be a little less than the typical elementary school teacher taking a typical path. I may have even a little less because of that. I don’t know, maybe if I had…The path I had originally chosen was to be possibly a school psychologist. I think if I had continued along that path, I think I would’ve had, you know, plenty of science to be a school psychologist, I think having chosen a different path probably when you get into the teacher education program, there’s a limited amount of science in there.

(Teacher #5)
I was in Home Economics with cooking and sewing, and then I went into Early Childhood. I think maybe more in Early Childhood because we would make more things. We would do more hands-on such as making Play-Doh for them to understand when I put the water into flour and the salt and the color and how it
mixed and became a pliable mixture rather than a powdery substance. I wouldn’t say my Home Ec information really helped at all.

(Teacher #6)

I remember a class but I do not think it was, that I was well-prepared. Other than really enjoying science, I don’t really even remember too much of that class right now. …we were undergrad…I was a child development major and I went, they had a partnership so I went to a different college to get my teaching degree. I did it in five years because it took a while before I decided I was doing teaching. It could be done in four years at that time.

Right, I took biology and you had to take, to graduate, you had to have so many credits and I did take biology.

(Teacher #7)

Liberal studies. Liberal studies. Yeah. I think there were some professors that prepared me, in a way, to think differently than how I did about how what science was. I remember there were some professors that just taught me all kinds of facts that I had to write down and regurgitate, and that wasn’t fun. Seeing how they prepared me for ways that I would and wouldn’t want to teach, but I don’t know if they were specifically how to teach science classes, courses or parts of those courses that I really remember having any sort of significant impact on my education that I can just pull. I do remember just how some of these teacher taught. Some of these science teachers for some of the science courses. Just remembering what they did. If it was interesting or not, or how they went about teaching concepts made an impact on how I would choose to teach my own students.
(Teacher #8)
Liberal studies. There was one class, and I don’t even remember…I think it was a geology class that the teacher actually made us do a lesson in front of the class by yourself. She helped us plan it, and she helped us kind of get ready for it, so we felt like we were supported, and really organized, planned and ready to go.
Confident in our lesson, then then we have the teacher in it in front of, which is scary, especially to do in college class when you feel like everyone is judging you. That’s the class I remember out of all my science classes. That’s the one that she made me get up there and actually teach a science lesson, and it was on the layers of the ocean. The other classes are, like I said, I took notes, passed the test, sat there and listened to the teacher, like most of those undergraduate college classes. Meh.

(Teacher #9)
No, not really at all. I mean that doesn’t mean that I can’t read some books and get some things of mine that pertain to maybe first grade curriculum. In college, it really didn’t prepare us.
Yes, I was liberal studies.

(Teacher #10).
Yes. [Liberal studies]…we did have biology and chemistry. I had some physics in there, too. 3, no, 4. I’m sorry, I had, what is it called, it was basically the life cycles and ecosystems, so I actually had 4. But they weren’t, I wouldn’t say that. You know you can sit in classroom but until you actually go out in the field it just feels like a continuation of high school. You’re learning it, but you’re not really applying it and so…
Lecture, read the book and assignments. It wasn’t a whole lot of going out into the field and teach this, which I think is more beneficial for a person to actually apply what they know or what they’ve been taught and go out to the field and see if you could try to teach that. I know they did that with P.E., with my P.E. classes that I did. We actually sat in lectures and everything and applied it in the gym and then were actually… One of our assignments was to go to a school and teach a P.E. lesson which was, you would think they would also require that for science. But they don’t.

There wasn’t a whole lot of hands-on to be honest with you. Yeah, I’m more of a hands-on and I think that’s if you actually doing something you’re more likely to remember. Than just sit there and be, some people can do it, but I’m more of a let’s go out and do it.

(Teacher #11)

I don’t think it prepared us enough. You took your basic science classes…Liberal studies.

Teacher Preparation Program

(Teacher #1)

In the days when I got my teaching credential, which was in 1996, we were doing Whole Language. You would study, everything you did was interrelated with each other. If you were studying the water cycle you would read about it, you would write about it. Your math would be related to it too. It was science, but sort of in a holistic way. Those were the days I got taught, but now I don’t say that we’re doing that so much now.
I think it was the idea behind it. Lots of hands-on. Lots of experiments. Those theories were taught to me for sure. It’s just the reality of implementing them. They leave out like ‘Who’s going to buy me all these resources?’ Those questions they don’t mention in the program and you get to your own room and so much of what you’d like to do you’d have to be willing to pay for on your own so that’s an issue.

(Teacher #2)
Probably not to the level of depth that it should have. I remember that I had one class that had a joint focus, teaching elementary math and elementary science and she split the time evenly between it. I enjoyed the science portion a lot. I enjoyed the math, too, but I felt that I could have gotten another… Just fully concentrated on teaching science and it would have been really beneficial.

(Teacher #3)
The teacher education program didn’t… I didn’t feel equitably prepared to teacher science. I learned on the job.

(Teacher #4)
I think that when you come out of the teaching program, you have some things you have to learn along the way that you might not have been best prepared for. I know there’s been some changes, I don’t know specific to science what changes have been made since I came out of the teaching program.
I think that there’s a point where it should be shown more and maybe it is more now shown how easy it is to integrate science into the other things that we do.
I remember doing a science lesson, I remember doing a week of science or something like that. That’s not enough to be able to teach, I don’t think it’s enough. I think it’s come with experience. I’ve come across a lot of teachers along the way that I’ve taught with, or new teachers, even, that I think backup when it comes to science. I don’t know if it’s just a level of comfort or probably especially having been a psychology student and then transitioning to that program, maybe you get more in the liberal studies program, but probably, I should’ve been required to take some more specific, maybe not just science, but maybe some other courses as well.

(Teacher #5)

None. It didn’t at all. Well, I can’t say that. I did take geology and I did take biology. It taught me about frogs and the environmental studies but that’s about it. My education, my degree was in the late ‘70s.

(Teacher #6)

No, we were undergrad.

(Teacher #8)

Actually, I have an early childhood multiple subject credential with a concentration on science. I took four extra classes in science to have a concentration.

Like, it gave me good ways that I would want to teach science, but actually like… I don’t know. Actually to walk in and be like, ‘Now I can teach science,’ I don’t know about that, but thinking back, we did lessons where we went to some parks and things, and actually got to do hands-on things. Lessons that were in a lesson book, but I haven’t done any of them with my class.
(Teacher #9)
No, not really. I had a master teacher, my student teaching experience was kids of different than how they do it now. I was in one classroom for 18 weeks, a fifth grade classroom. And the teacher absolutely didn’t teach science, so therefore, I really wasn’t exposed to that. I didn’t teach a lower grade. Now student teaching is an upper grade and a lower grade, I only got one for a whole semester. So I went through the University of Xxx Xxxxx, and I don’t know, I didn’t feel prepared through the student teaching or the courses.

(Teacher #10)
There was just one science class and again it was more of a lecture type of program. I didn’t really get a whole lot out of it.

Resources

(Teacher #1)
On top of that, I don’t have any resources. I don’t have computers. I don’t have any materials to do anything with. I’d have to buy them on my own. My priority, I have spent a lot of my own money but it’s been mostly on books because even more important than science is I’ve got to get them reading. That’s my biggest job this year so I have a certain amount of my personal money I’m willing to spend on my job and my list of priorities, it’s been on books over anything else. I’ve invested in books. I would love to- it’s spring. I want us all to plant seeds and grow them in pots, but am I willing to spend all that on my own money? Am I willing to? I’d love to watch ladybugs hatch and caterpillars. I’d
love to have a tank of tadpoles and watch them turn into frogs, but who’s going to – that’s my own money.

In an ideal world I think you’d have a science specialist. That would be one of the things you did like the tech lab…

My dream in my head is the other things I was mentioning. I have to decide if I’m willing to put that much of my own money into it. It’s a big factor.

I was planning on planting seeds this spring and watching them grow. I actually got so far as to have it in my inbox ordering it online. I just held it there because of the money. I just at the end decided I would rather buy reading books with that money because I can use them year after year after year.

I actually switched and bought books instead and didn’t buy the seeds.

I just need more supplies and that I don’t have to pay for… I need more help. I have 27 kids and they’re all seven years old so I need another adult in there if I was going to really do it well. I need help.

Having more help. The school buying us more resources.

(Teacher #2)

We’ve just finished raising butterflies and observing the butterfly life cycle, life cycle of the frog before that and we are comparing the two life cycles now.

To a certain extent also materials, because it seems like there is a wealth of materials for math and the ELA. You are sometime scrambling to find the materials or paying for it out of your pocket more often than not. Like everybody else, I do that a lot, pay for that out of my pocket and just accept that it is part of my job.
(Teacher #3)
The other reason is because we got kits with actual items that we would need to conduct the experiments, whether there was a clothespin or yarn, whatever the project. There is no process for restocking the supplies that we need. And unless we decide to purchase that out of our own pocket, ask for donations, put it on some type of teacher wish list, there is no funding for those supplies, so once supplies get consumed, the chances of us going out and restocking that out of our own pocket is probably not going to happen. Which is why the experimental projects are far and few. We did them a lot, when the kits first came…If it was something that was consumable and it was easy, like we needed straws. That was no big purchase. But if it was something, like soil, that’s not something I would necessarily go and rebuy again. So, I would find another activity that would fit it’s place, which would be less money out of pocket.

We have science books, yes, we do. Well, I’ve been teaching the third grade for six years, so I’ve been using them for six years. I am assuming they were there before I got there, to the grade level.

There’s a total of four binders and we shared them as a grade level.

There’s not enough time. There’re not enough resources. And when you put all of those together in a 10-month year, it just comes down to…it’s not the priority, so that’s not what we tend to focus on.

A combination of using the district adopted textbooks and whatever resources that we find as a team on other sites, or what happening or just looking at TPT (Teachers Pay Teachers), what’s out there, and then creating something that’s been all our own.

Besides time, having the resources. Oh, yeah. I would do it a lot more, because I like science. I like science and social studies myself. I wish I had more time and I
wish that I had a way to continuously fund that materials that it would take to give them a hands-on experience.

I think if we had the time, if we had the resources, if it was the focus, it wouldn’t be what I perceive as a daunting task…

(Teacher #4)

It’s been a long time since we received a new science book or a new science, any new science support or anything that’s provided in that type, it’s been a while. I don’t remember what year it was that we received science materials. 2007. We use it, but not as much as some of the other books they use…along the way since then found materials that are better than the actual book. We refer to that book and we use it, but not as much. We don’t go through the whole thing…

I think time is a big part of it. I think the interest is there I think, I wouldn’t say we have the best materials provided to us…I think there are plenty of things out there that we can access and we can find. I think the biggest inhibitor is the time, is just getting it in there.

We have ladybug larvae and butterflies coming. I purchased those. I spent probably close to $50 last week just ordering, and that’s already having the kit that can be an example of a reason why a person or a brand new teacher does not want to go and spend hundreds of dollars on all kinds of materials throughout the year, and here we are thinking about doing some other fun things here in April. We’ve already spent quite a bit of money. That’s me already having the kits, already having the habitats for them. Without that, it would probably be closer to $100. People get to a point, it’s that picking and choosing. You can’t do it all.

Goes back to time. Time’s an issue. You’d think 18 years later, I’d fine tune something in the same grade level.
(Teacher #6)
Well, providing experiences and whether it’s as many hands-on things that I can do. But the trouble is sometimes it does involve resources or taking the time to save up the tin cans or whatever you need for and I do think because of that sometimes we don’t do as many things as…It’s a little more labor intensive to sometimes do the things that they really enjoy.

Good resources, clear standards. We wondering when we get Space this year, we said it’s not going to be a standard next year. Then resources and it’s not always monetary, it’s sometimes just taking the time to gather the supplies that are needed.

Having a curriculum map. For us and some ready-made guidelines and then, that would make it a lot easier. Just have a curriculum map or at least units. Maybe not so much when you want to do it and then possible lessons and then finding not necessarily a textbook. Because that’s not always, I don’t think, you can find just one book unless they’re going to write a new one. Just find lessons, activities just to help us out.

I was going to make a trip to the Bay Area and I thought I would go to the RAFT visits. It really is a nice resource and it just didn’t work out. I haven’t seen anything free to go to, I mean free with membership.

(Teacher #7)
What I think would be super good help is having materials. I would almost think the materials would be great, but we’ve been given materials and never use them. That’s one thing that I would think, like, ‘Man, I don’t have enough time to prep. Well, there a tub of pre-prepped materials,’ and that hasn’t really helped. I think
what’s really helped encourage us or motivate us is when we are on the same page. Because we both went to that training, and we both decided, ‘Hey, we’re actually going to do this on this day…’ We’ve put it out there that we’re going to, and then we actually get the materials, which was a secondary thing.

…if your team is doing it, that definitely motivates to actually do it well. Because a team is working on it, it’s so much easy to prep for, and all the materials worries are kind of non-existent, because that doesn’t really matter…That’s just what it’s all about, I think, is colleagues encouraging one another to do it, partnering together and actually deciding to do it.

(Teacher #9)

We don’t do a lot of science experiments, you know, we try to bring in as much real life stuff as we can, for instance we just did the life cycle of the butterfly, so we got caterpillars that went into chrysalises and unfortunately, they missed the butterflies coming out of the chrysalis, but that’s science at our level.

By the way, I’ve purchased every book in the listening center on my own. I’ve spent hundreds through Scholastic.

It’s been a long time since we’ve had science curriculum. I don’t know when they stopped giving them to primary, but the whole time I’ve been in first grade. Well, no I take that back. I’ve been in first grade for about seven years, and we had these consumables once…at least five or six years.

We buy these consumable books for ELA, skills practice pages that I don’t touch. And I get these same books every year, and at the end of the year, I might tear out one or two or three pages, $25 a child for these books, and by the end of the year, I’m sending almost the whole book home. I hate those skills books.
Are reading and writing and math. And we do spend a lot of money on those three areas. Probably our whole budget. Whatever our budget for the district.

I feel a little bit like I’m copping out because where there’s a will, there’s a way. I could find some resources. And probably free resources, but it’s not handed to me. Maybe I’d be more likely to do something if it were part of the curriculum. Facilitator meaning like help? The biggest help? Besides having enough time? Probably some laid out activities, some step by step and supplies provided, you know, gathering things for any kind of activity, hands-on, for small groups. Another facilitator would be another person in the room, maybe two more people.

(Teacher #10)

It’s a tough job. I’m exhausted. Sorry, I don’t exactly want to do it every day, I mean, with 26 first graders. I think it would be great, but the chances of them actually, you’ve got probably 50% that are actually trying to do it and then you’ve got the other ones that are messing around.

Yeah, we were even able to, we have a new unit with our ELEs, it was about the life cycle of a butterfly and so I ended up buying.

I would say materials. I mean I can’t go to the rain forest. I can take pictures but that’s the same as seeing them in books. It’s hard with our units, I can’t always bring something outside the classroom, at least for the life science. I try to think of little things that I could bring I that they could see and feel and touch. But, that isn’t always the case, it’s finding those materials for them to be able to put their hands on… I don’t mean materials as far as like pen and pencil to paper, but materials as in like, when I got those caterpillars.

Have you seen the stuff they give you? It’s like, you have to put more stuff in it. You have to go out and find the stuff, it’s more like, it’s more like. I have, it
almost looks like a little cage and I have to go out and find the materials to put inside the cage. I need additional stuff to be able to work with what they gave me…They can’t come with caterpillars, you know.
If I could have anything, it would be nice to have a science teacher. That’s all they do.

(Teacher #11)
That’s usually, simply because of time, too. It’s always about time. I think not having the material that you need, the resources that you need. I think sometimes that’s an issue, so you have to go through and gather all that stuff, which is what we do. That and the fact, well, no, that would be it, because we continue to teach it no matter what, so we’re just waiting for the new standards to come through, or at least for them to tell us what they are.
I think maybe if they had workshops available to attend.

Teacher Attitudes toward Teaching Science

(Teacher #1)
…that light inside them hasn’t been dulled yet at such a young age, so they think it’s fascinating to learn about a jaguar or a fossil or even watch a plant grow.
Those things excite them at the core and energize them and I think it’s part of the innocence of being so young.
When I feel I’ve done a good job with those subjects and I can take a minute at the end of the day. Usually it’s Tuesday or Thursdays I’ll bring in science. It isn’t given to me as a high priority and it’s not just what I think. I’m guided by what people are telling me to do.
I think it was taught the idea behind it. Lots of hands-on. Lots of experiments. Those theories were taught to me for sure. It’s just the reality of implementing them. They leave out like ‘Who’s going to buy me all those resources?’ Those questions they don’t mention in the program and you get to your own room and so much of what you’d like to do you’d have to be willing to pay for on your own so that’s an issue.

I think it’s a short window where you get that enthusiasm. [And the curiosity?] Oh, it’s killed by the next couple of years. It really is. I know that from my own three children. It’s because you just get this big heavy textbook plopped down in front of you and have to just read it and then answer questions on it, take a test on it. It’s enough to just kill you.

When science becomes just another big heavy textbook that you have to open up and read, choral read or listen. Take turns while your friends read and you’re just sitting there? That’s really boring. I don’t care what the topic is, you’re going to be bored.

…it’s not just about me or what I think or what I want to do. I wish it was but it’s not. I’m guided and I’m controlled, very highly controlled about what I’m supposed to be doing all day long. I’m told what to do.

I want them to see things happening in front of them. I want them to watch a tadpole turn into a frog. I want them to plant a seed and feel the soil in their hand and water it every day and look at it and watch what happens. I want them to do all that. I do. I really do.

We have to do similar things across grade level.

A second grader’s attention span doesn’t even go through the whole day really. They’re starting to fade by the afternoon anyway. I’ve got music, library, tech lab.
Mondays, Wednesday’s early release, Friday we’re mentally shot by the end of the day.

[Is that why you try to do science on Tuesdays and Thursdays?] It has been. Yeah. But let me qualify that. There are times when I have to switch to small group Math groups and intervention type activities instead because if it’s a hard unit like a hard math unit of something, I have to let go of the science a little and got to do more emphasis on the small groups intervention for Math. I’ve used [that time] for that too.

However, if we can’t get them on grade level or above in reading and math then it won’t matter. Science won’t matter so much if they don’t have the basic academic skills.

It won’t help them in science if I can’t get them to be good readers. That has to be my priority.

I think it’s crucial to building their enthusiasm for learning and keeping them in tune with the world and exploring the world that they live in and seeing it in new ways.

I actually switched and bought books instead and didn’t buy the seeds.

I would be careful not to overemphasize the role of the teacher in this because I don’t feel, at least in the public school system, that as a teacher we have this huge amount of control of our day. It’s very controlled for us…I don’t feel that – I don’t have as much as importance as maybe this is placing on me in terms of what I can do.

By the time you’ve tried to get through all that, you’re just exhausted and the day’s almost gone. I guess I’m just saying whether I’m great at teaching science or whether I believe in it or not isn’t even barely the point. Because I don’t have a huge amount of say in it anyway.
(Teacher #2)

For me, science education includes all aspects of teaching them scientific inquiry, learning how to approach a scientific question, being exposed to scientific higher level vocabulary, going through a kinesthetic process of actually exploring materials, looking for causes and effects, and being able to talk about what they observed. That’s probably more directed down to the kindergarten through second grade level, but that’s my world, so we have to be able to touch it, talk about it, figure out what happened and why, but definitely trying to given them a foundation of the scientific method, and getting them curious about how the world works, and how to explore it appropriately.

You can’t just read about it. We have to be able to see it in action, so when we talk about weather patterns, we go outside to observe them. We’re touching the crinkly fall leaves that have fallen on the ground, we’re smelling the air, and then writing about it, talking about it, drawing pictures of what we observed, things like that.

I love it. It’s a good pathway to a lot of different curriculum areas…There has to be a way for them to connect to it, for it to be meaningful for them, and science is a good pathway for that.

I enjoyed the science portion a lot…Just fully concentrated on teaching science and it would have been really beneficial.

I would say that we probably do a lot more life science than anything else…We have more life science I think than we do physical science and…Back then trying to remember what…We did a little thing on the water cycle earlier this year and observed clouds, clouds’ structures and different types of clouds, that was exciting, we covered states of matter and did some observations on things
changing from a solid state to a liquid state, because it is a classroom, it’s a little harder to get to the gas state in here. So we talked about steam in the shower or…I did a little video of cooking spaghetti and they got to see the steam and watch the water boil. I think that’s about it so far, there is still time.

I know that science is a priority as they move into the upper grades but I don’t see that much at the elementary level.

I think that it is critical that our students learn about science because that is a direct path to being innovators. We need innovative thinkers and we need kids who feel comfortable questioning something and trying something and failing. Where else do you get such a good opportunity to try something and fail, and try again and have it be acceptable, if it is not in science? I think we’re doing a better job of teaching our kids that it is okay to make a mistake and try again. Science is just an open world for that and how are we going to continue to be innovators in the world if we ignore science?

In our classroom, in my classroom, it’s absolutely okay to make mistake and my kids would the first to stand up and tell you, ‘We just learned something new from that,’ or ‘Our brains just got bigger because we had to try something different.’

It’s definitely a concept that people need to be comfortable with like, ‘I tried that and it didn’t work, what can I do next? What can I try again? How am I going to try it differently next time to see if it would work better?’ It is definitely a strategy that you apply to math and you apply to reading and you apply to writing. I feel like we are just better about talking about it with science.

I think that anytime you see them active and really physically connected to an activity, it cements that learning in ways that will just last a lot longer. Then, of course, they are little bodies that need to move and not everybody loves to read. If you are spending ninety percent of your day in English/Language Arts, you only
gave ten percent of your day to those kids who need the science a lot more. They need that extra tactile piece that they get, that encounter with in science.

I don’t think that is fair that those kids have to wait that long for the one time, that week that you decided to do science. It would be nice if we had a lot more time for them.

Yeah, and then for those kids who are the verbal linguistic, it is the way to challenge their minds and get a new vocabulary or a new skill set going for them. There is automatic differentiation built into it, which is really nice also for living in a community that we have here, with it being a Title 1 school. That in teaching vocabulary, those enriching experiences aren’t always present at home. So, it is important for them to have that here.

Science is awesome and it should be more of a priority.

It would just be nice if it would fit in daily. I remember it used to fit in daily when I was in elementary school and I have no idea how they worked that magic, but we had science every day.

(Teacher #3)

Science education would be content area knowledge with application like experimentation, experimental hands-on learning, as well as content learning. We’re trying to kill two birds with one stone.

I feel like we do better than most, but we’re not anywhere near what a good science program should look like or what it should be.

I would do it a lot more, because I like science. I like science and social studies myself. When I get on a topic I can easily move above and beyond. I don’t feel that obviously, just for me, the content is scary. In fact, that’s interesting, it’s fun,
it’s engaging already for me. So, I hope that I present my own enthusiasm and my kids feel that.

I think that we’ve done better to integrate cross-curricular items so that we can get bang for our buck when we’re teaching because that’s what you have to do. You have to be teaching multiple standards at the same time in order for it to be, well, time-consuming. It means something, so the kids are connecting that science isn’t just in isolation.

So, I’m glad that since there was a shift has been…to what we didn’t shift all to experimental, that our shift was more to the other end as far as researching and that.

They mirror each other in the research process so the kids need to understand that reading and writing are so important to be a good scientist. So, once they get that, then hopefully to love of the subject gets them motivated, because that’s where they’re going to be going.

The kids have to understand that the product is everything we did before the product.

(Teacher #4)

I do enjoy teaching science, mostly because I think it’s very high interest for the kids…if they’re really excited about something that you’re doing, it’s a lot easier to get everybody to buy in.

…when I’m going through our science, it’s mostly because of the kids’ enthusiasm with things that we’re doing in science. Science, yes, I definitely enjoy teaching science.
If you’re not confident in what you’re doing, you’re going to do it but you’re probably going to do a little less or not as well. I think if you’re experienced with something, you’re going to go to that a little more easily.

I think it’s hard, it’s almost in second grade, having taught second grade for all these years, it’s almost hard not to do it because the kids love it so much. Sometimes if you see someone that’s not really doing science or not really eager to do science, it’s almost unusual because it’s got to be a comfort level thing, because the kids love it.

I think it’s very easy to do group structured activities. We’re not doing this year in particular a lot of experiments. Some years I’ve done more of that in the past, but some of our standards include magnets and life cycles, so we do try to do, I do try to do, a lot of hands-on activities for the kids.

We try to do a lot of hands-on, like I said. I guess that’s the best way to describe it. Group activities, partners, and then kind of revisiting everything whole class.

I feel like it is just as important to learn about science as it is to learn about all the other curriculum.

I want them to develop all those skills, but because you can’t incorporate science and the science topics into that, I think it’s just as important.

Science is all around us, our world, our experiences. There’s all kind of science-related, and I don’t think that that’s always taught or developed. Yes, I think it’s important.

I think that’s really easy for them to get up, get physically up, move around, there’s all kinds of activities they can do obviously at their seat, but I think for second graders, it’s really conducive to group learning, cooperative learning, all kinds of things that you can tie a bunch of things in together. Activity part is important.
I think for me, just because I enjoy science, I think that becomes the easiest thing. I like to when I can incorporate it in. With the balance of everything that we’re always balancing. I enjoy it and I feel it’s important, don’t always feel that even with that, I don’t feel like I do enough science. Lots of times throughout the year I’m like okay, I’ve got to do more. I haven’t been doing enough of this, or I haven’t been doing enough of that.

I know a lot of times where I didn’t do any of this unit or this and that, and that unfortunate, because I think the kids deserve some science foundation just to keep that interest. Otherwise, you’re not going to have kids that don’t even know they’re interested in science by the time they get throughout the grades.

(Teacher #5)

I do [enjoy teaching science] because it’s basically non-fiction text and it causes children to think out of the box…

I think it’s important for them to learn about it, especially the comparing so they can see different comparisons, for them to be able to see the data.

I think for kids to have more hands-on. If we’re studying biomes it would be neat for them to be able to go to, maybe to see the wetlands.

(Teacher #6)

I love teaching science. I have lots of hands-on things. I love science. Especially things in nature, it’s just…you have the students right away, they’re already engaged.

It’s just a way of to teach reading. When we teach science in third grade and maybe this sort of answers that constitutes science education, when we teach science we’re teaching reading through science.
In third grade we’re still teaching reading but we use science as a tool. But they don’t always know if they’re…they could be doing cold read or something that’s science topic and they don’t know it’s science.
Whole class: read a leveled book, "My Sheep." (projected on screen). Teacher reviewed a second book, "Wool" with class: higher level, more detailed text, and better pictures. Teacher showed real wool samples with lanolin--explained and passed around. Teacher showed combed wool and yarn in various stages. Teacher passed around, or showed, various items made from sheep (realia such as: sheepskin, lotion, Carmex, fake meat, dog food label, scarf, sock, mitten) Students watched an educational video about sheep-shearing in Australia.

none

Learning about plants: class discussion about the parts of a plant; introduced an observation of root vegetables in a tray of water to see what happens over time; readers theater about seeds and how they travel; reviewed and added to our questions about plants.

Small groups listen to the Wonders articles "The Moon's Shape" and "Pluto" and filled out the summary frame.

Today our class read a Close Reading article comparing a butterfly's life cycle to a frog's life cycle.

When you put today that really limited me. None today because we don't do science every day. However, I have done all of your examples except student-led demonstrations many times throughout each chapter.
We are in the middle of Open House so we are knee deep in our science animal unit. Today we completed Biome Dodecahedrons, completed Science Ch. 4 Review, and wrote our habitat and life cycle paragraphs on our group animal reports. Students also brainstormed on combining two animals from the wild (ex. "Rhida" -rhino and a panda). We discussed how the combination would effect their habitats and what they would have to do to adapt to work for both animals.

We read a passage regarding plants and butterflies. We discussed several things we learned from the passage. We pair/shared with a partner three things we have learned from the passage. We Made a word wall of all the interesting and important words from the passage. And finally wrote five sentence informative writing piece on the subject. The entire process took about 20 minutes teach. And each student took about 20 minutes individually to write and draw a picture.

None – did some history today – no science.

In coordination with our writing activities for the day, we learned about jellyfish (the writing topic was "Would you Rather swim with a great white shark or a box jellyfish). The students were really interested in how jellyfish sting, eat, etc. We watched a couple of youtube videos of how they sting, eat, etc. and had a teacher led classroom discussion about what we learned and how we can apply that to our opinion writing later on.
Today we discussed and observed various seeds and roots. The children have very deep questions regarding plants and how they work. We went on a root hunt around campus with our science journals to record new questions and observations. We harvested vegetables from our school garden and talked about where plants store their nutrients. We brought back several examples of roots and other parts of plants to observe further with a microscope and hand lens. We also read a book about roots to reinforce some of the observations we made earlier in the day.

Today we read a passage about ants. After reading the passage twice, we pair/shared with a partner about 3 things we had learned about ants. Then we used the information learned to write a 5 sentence informative writing paper regarding ants. Teaching (reading the passage, pointing out what was learned, building a word wall and reviewing the format of Informative Writing) took about 15 minutes. Student writing took about 20 minutes.

Same as yesterday for the other half of the class: small groups listening to Wonders "The Moon's Shape" and fill out a summary frame. Teacher introduced a chapter in the science book: "What patterns repeat every year?" p. 236 – 239. Students read the pages together in groups of 3 or 4.

This week we are learning about social studies and not doing science. Boo! I cannot help you. Unfortunately, I cannot teach both science and social science at the same time. I wish I could.
Read a chapter, discussed text features, and looked up vocabulary about animals and plants.

Mon. April 4, 2016 - Students continued collecting bulleted facts on their biome. Students were to write at least 21 facts. Next they categorized the bullets into the following: Introduction World=% of land mass, where (continent, country) Weather Vegetation Adaptation Survival- food, water, protection Conclusion

Tuesday, April 5, 2016 Students continued documentation, finalizing their bullets and facts. Some are starting to write their paragraphs. Teacher showed students the template for entering their paragraphs that is located on Google Classroom. Template was created jointly by technology and classroom teacher.

Tuesday – sadly no science! Scrambling to complete art and writing for next week’s Open House!

Today we read another Close Reading article titled Monarchs on the Move we also did a read aloud titled From Caterpillar to Butterfly. We learned about migration, hibernation and the life cycle of a butterfly. In addition, the students colored pictures of the life cycle process, sequenced them accordingly, and then wrote a brief description of each stage.

Class discussion on the ocean habitat, students researched ocean animal by choice and looked at their adaptations (videos, books, online websites), annotated information read, filled out a graphic organizer to collect information.
On April 5, 2016 we did not do science.

Monday and Tuesday we took note on the four different tribal groups of California. The students have been learning how to take notes and then write paragraphs. They picked one tribal group to write a paragraph about.

Today we learned about the American Indians trade and government. After reading the textbook, the students got into four groups to play a game about trading and bartering. Each group was given a bag of items. On the board, I listed the items they must have at the end of the game. The groups had to work together to decide what items they were going to trade and who they were going to trade with. Only the leader of the group could do the trading. The leaders met in the middle of the room to do their trading/bartering, then returned to their groups. Each trip, they "traveled" with only the items the group decided they would trade.

Today we drew the life cycle of a butterfly, added pictures and captions of each stage. The students are also working on a project called Insect Brochures.

None today - early release day.

We continued to talk about seeds and roots in a collaborative discussion. Some children made new observations in their science journals of the plant investigations in the science station. Children continue to wonder and ask questions. As we find answers to some questions, we form new questions! We made terrariums with plastic soda bottles and discussed how we think the seeds
that we plant will grow. We read The Tiny Seed by Eric Carle and discussed how seeds travel and what seeds need to grow.

Students studied Environments in the reading station. We do stations Monday, Tuesday and Wednesday. The students read the Science Reader "Living in Different Environments" They read this over a three day period in the stations and answered the essay questions at the end. The students did this as a small group. Using the Scholastic News - students read about solar powered cars and the effect they will have on our future and the environment. We discussed energy/stored energy.

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Wednesday: Students studied Environments in the reading station. We do stations Monday, Tuesday and Wednesday. The students read the Science Reader "Living in Different Environments" They read this over a three day period in the stations and answered the essay questions at the end. The students did this as a small group.
Wrote a paragraph on a group animal interesting facts, created a "morphed" animal and determined what biome it would have to live in, Ch. 4 open response questions in science.

Wednesday: My student teacher began a unit on water cycle. Read half of a Disney book titled: Mickey’s Weather Machine Read the winter and spring portions which got us through the rainy weather. After lunch did a “Rain in a Bottle” experiment, completed a worksheet with water cycle vocabulary, and watched a Magic School Bus episode “Magic School Bus Gets Wet” About 2 hours of science today. Woo hoo!

Reading and annotating text on animals in the arctic habitat and followed with a class discussion on arctic animals adaptations and why...students made connections with national geographic video that was shown.

Wed. - April 6 - Students writing paragraphs from their bulleted facts. Went to Computer Lab - introduced the work template that was placed on Google Classroom that students. Students were told that their work must be peer edited then self edited before typing information onto the template. A few students were ready to start typing.

Thursday, April 7 Students continue with fact finding, editing, and typing of Biome project

Today we read a passage about Baby Chicks. We thought about all the things we learned about baby chicks. Then we pair/shared 3 things we had learned with a
partner. Next we created a word wall with all of the words we might need for our writing. Last we used what we had learned to write an informative paper about Baby Chicks.

Today we discussed other sea life in coordination with our opinion writing unit (would you rather swim with a shark or a jellyfish), also in preparation for our fieldtrip to the zoo.

Creating written biome for "newly discovered" combined animal (my favorite has been the Weaver - whale and beaver and the Porcanda - porcupine and panda :) Study Guide for Science Ch. 4.

Today we observed that some of our seeds have sprouted! We also read Tops and Bottoms to continue the discussion of where the plant stores nutrients and how we eat that part of the plant (e.g. we eat the root of the carrot and the leaf of the lettuce). We started collecting data in terrarium journals for the terrariums we made yesterday. The terrariums have a string to suck the water up into the soil in the top part of the container. Children were anxious to touch the string today to see if it was wet and the water was getting to the soil. We also talked about stems, made observations of celery under the microscope, wrote in our science journals, and put celery stalks in colored water to observe the function of the stem. Students noticed tubes as we were observing the celery pieces!

Students read their Scholastic News which was about alternative food sources such as insects. Students learned how insects are easier on the environment than
other things such as cows and chickens. Students used RACE to answer questions about the article.

Today we read 3 poems about insects and did close reading annotations. We also drew another diagram of a butterfly's life cycle and labeled the stages. Finally we watched a Brain Pop Jr. video on Insects and did one of the quizzes together as a class.

Students worked on planet reports and PowerPoints.

After reading the lesson on celebrations and storytelling, I had the students work in groups of 4 to create their own story map. I wrinkled up a pre-cut folded brown paper bag. It was folded into 8 squares. They had to retell the story in the book using only pictures. Each person of the group drew two different parts. After, they shared aloud.

Thursday : review of water cycle, rain making activity - finger snaps for drips and drizzle, etc. 10 minutes

No science today…focused on math, mostly. (Although we did use sheep in our story problems with logical stories: “A ewe had twins…now how many sheep does Farmer Bob have?”—kindergarten)

didn’t

Thursday, Brain Pop on biomes
Today the students are making flowers to go along with our insect unit representing the nectar they gather.

We did not do any science today.

Today our seeds had sprouted even more! The celery showed that the colored water had reached the top of the plant. We had further discussions about our observations. A child also brought in some passion flowers from their yard. We were able to observe the parts of a flower up close under the microscope. One student found a ladybug at recess and read a book and learned how plants and animals interact.

Mini quiz for me today. I'm at jury duty and made a little quiz rather than have my sub teach.

Today we read a passage about Owls. After reading the passage, we pair/shared with a partner all of the things we had learned about Owls. Next we created a word wall of all of the words we might need for our writing. Last we took the learned information and wrote an informative writing paper.

We didn't do any science today :(
Friday: Technology issues: Students unable to type their information in the created Google classroom template. Students had to retrieve their completed paragraphs from their Google Docs which saved automatically from Google Classroom. Then teacher instructed students on creating a google doc with a two row table. Students were then able to type their Biome facts onto the Google doc table.

Open book Science test

Thursday: had a substitute. In the continuation of our unit on Farm Animals, she read a book about goats, had a discussion with the students, and did a KWL chart with them. Friday: reviewed with students the KWL chart that they did with the substitute. Talked a bit about how sheep and goats are similar in many ways

Sorry! No science – finishing writing & art projects for Open House next week. We always need more time!

No science today.
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