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How Teachers are Making Sense of the Next Generation Science Standards in Secondary Schools: A Mixed-Methods Study

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How Teachers are Making Sense of the Next Generation Science Standards in Secondary Schools: A Mixed-Methods Study

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Education

in

Educational Leadership

by

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This Dissertation of Christina L. Wilde is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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2018

DEDICATION

To my mom. Thank you for telling me to follow my dream.

To my husband Brad. Thank you for all of your support and for believing in me.

To my children, Nathan and Jessica. Thank you for all your help around the house, understanding when I had to miss school events, and for learning how to cook your own dinner.

To my best friends, Danielle and Maria. Thank you for meeting me every morning at 5:00 a.m. to work out and for listening to me obsess about my dissertation for the past three years.

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To my colleagues, who had to tolerate me juggling my career, my graduate work, and my family: thanks for your patience and understanding.

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VITA

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National Science Teacher Association	2015 - Present
Association of California School Administrators	2012 - Present

ABSTRACT OF DISSERTATION

How Teachers are Making Sense of the Next Generation Science Standards in Secondary Schools: A Mixed-Methods Study

by

Christina L. Wilde

Doctor of Education in Educational Leadership

University of California, San Diego, 2018

California State University, San Marcos, 2018

Christopher P. Halter, Chair

In 2013, California adopted the Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve (CA NGSS), which set the stage for how science should be taught in every school throughout the state. Since the NGSS represent a change in how science instruction should be delivered, many teachers are now facing the difficult task of understanding these new ideas, identifying how their current instructional practices align with the NGSS, and translating and implementing these new practices in their classrooms. However, changing teacher instructional practices is not accomplished quickly or easily because teachers bring a variety of knowledge, beliefs, and experiences to standards-based reform efforts. As a result, when educational change is required, educators do not all respond the same way. Therefore, using a conceptual framework that drew upon literature on teacher sensemaking and policy interpretation in education, this mixed-method study investigated teachers' experiences as they translated the NGSS into their own practice. This study centered on the perceptions and experiences of 37 secondary science teachers in two different high school districts in San Diego County. Based on survey and interview responses, findings from this study suggested that teachers were starting to develop some common language and understanding around the NGSS. Moreover, teachers had some understanding and knowledge of the instructional practices associated with the NGSS, which in turn was initiating changes in classroom practice. But teachers were less confident about their skills and knowledge regarding science and engineering practices and how to use the NGSS performance expectations to assess student learning. Additional findings also indicated that teacher beliefs, emotions, networks, and school contextual factors affected how teachers made sense of the NGSS.

Chapter 1: Introduction

The K-12 science education community in the United States has entered a new period of standards-based educational reform. With a growing need to produce a workforce with strong science, technology, engineering, and mathematics (STEM) backgrounds, declining student test scores, and new research about science education and student learning, there was a widespread call for a new approach to science education in the United States (Bybee, 2014; Kay, 2010; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; National Research Council, 2012; National Science Board, 2007; Trilling & Fadel, 2009). In response, Achieve, an independent, nonpartisan, nonprofit education reform organization, coordinated the work of 26 Lead State Partners and collaborated with critical partners, including the National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science, to develop the Next Generation Science Standards (NGSS) which were based on the *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (hereafter referred to as the "Framework"; NGSS Lead States, 2013).

The NGSS represent a change in how states have traditionally approached their science standards. In embracing science education research, the NGSS represent performance expectations that will now require all students to have a deeper understanding of a smaller number of disciplinary core ideas, show evidence of that knowledge through scientific and engineering practices, and connect crosscutting concepts across disciplines. The NGSS also build from grade level to grade level throughout a student's K-12 science education. This design was based on the idea that science concepts should build coherently over time in order to provide students the opportunity to continuously build on and revise their knowledge and abilities

(Bybee, 2014; National Research Council, 2015). Moreover, if these standards are implemented with fidelity, significant changes should occur in teacher classroom practices (Pruitt, 2014).

Yet, even though the NGSS do provide clear expectations for teaching and learning, implementing standards-based reform policies is inherently problematic (Hargreaves, 2005). First, the NGSS is a “policy document,” not a type of curriculum. Thus, implementation will require changes to existing science curriculum materials, assessments, teacher development, and instruction (Bybee, 2014; National Research Council, 2015). Second, policy implementation does not occur in a straightforward, unidirectional fashion across all levels of the education system (Spillane, 2005). Rather, because individuals at each level have their own unique responses to policies on the basis of their particular understandings, preferences, pressures, and timelines, a coordinated approach to policy implementation is often difficult (Honig & Hatch, 2004; Spillane, 2005). Lastly, a teacher’s training, knowledge, beliefs, and networks also shape how and what gets implemented in their classrooms (Coburn, 2001; Gallucci, 2003; Hill, 2007; McLaughlin & Talbert, 2001; Talbert & McLaughlin, 1994). Consequently, since teachers are the ones who ultimately decide what gets enacted in their classrooms, teachers are decidedly the most influential actors in the implementation process (Schmidt & Datnow, 2005; Spillane, Reiser, & Reimer, 2002).

Because teachers are such a crucial part of the educational change process, this study examined teacher experiences as they translated the NGSS into their own practice. Findings from this study contribute to the current literature by providing more insight into factors that may impede or support a teacher’s ability to implement a new standards-based reform policy. Additionally, this exploration of teacher experiences with the NGSS could be used by school leaders, professional development providers, district curricular staff, and instructional coaches to consider ways to better support teachers in implementing the NGSS. The need for science education standards reform, the intent of the NGSS, and the role of the classroom teacher helped to set the framework for this study.

This chapter presents the purpose of the study, research questions, theoretical framework, methodology incorporated to address the research questions, and the significance of the study.

Problem Statement

Currently, the United States ranks 17th among developed nations in producing science and engineering students, a decline from third place three decades ago, and is 26th in producing mathematics majors (President's Council of Advisors on Science and Technology [PCAST], 2010). Moreover, only about one-third of bachelor's degrees earned in the United States are in a STEM field, compared with approximately 53% of first university degrees earned in China, and 63% of those earned in Japan (PCAST, 2010). These statistics have prompted significant concern over the ability of the US to produce enough STEM majors to meet the country's technological needs. Recent estimates are that the US produces 200,000 fewer STEM graduates per year than are needed (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007). The shortage of engineering and mathematics majors is especially acute (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; National Science Board, 2007; PCAST, 2010). Presently, immigrant workers fill this mismatch between the STEM workforce supply and the economy's demand, but this is a short-term solution that soon will be neither politically sustainable nor economically efficient (Ehrenberg, 2010). As a consequence, policy makers have openly acknowledged that the United States needs a long-term strategy to increase the number of students entering STEM-related majors.

However, the reasons why students do not enter STEM-related majors are complex and varied. One reason has been linked to the lack of rigorous science content and inequitable academic achievement among different groups of students in the elementary, middle, and high school grade levels (Gamoran & Hannigan, 2000; Gándara, 2006; Moller, Stearns, Southworth, & Potochnick, 2013). In turn, these inequities have resulted in men, White, and Asian students, and students from higher socioeconomic status (SES) families graduating with STEM degrees at higher rates than women, African Americans, Hispanics, Native Americans, and students from lower SES families (Bottia, Stearns, Mickleson, Moller, & Parker, 2015; Chapa, 2006; Januszyk, Miller, & Lee, 2016; Lee & Buxton, 2010; Lee, Miller, & Januszyk, 2014; Lynch, 2008; Riegle-Crumb & Grodsky, 2010). Litow (2008) also identified the underrepresentation of Latino students in STEM as a “silent crisis” because although Latino students are a rapidly growing segment of the labor force, they have been severely underrepresented in STEM professions. Consequently, the underrepresentation of these groups in the STEM workforce not only has limited their participation in many well-paid, high-growth professions, but has also resulted in the absence of their diverse talents, perspectives, and inspirations that are essential to producing scientific innovation (Lee, Miller, & Januszyk, 2015; PCAST, 2010).

These reasons, along with new research about science education, prompted new questions about the current science educational practices in the K-12 educational setting. Prior to the NGSS, science education in the United States was often referred to as the “mile-wide, inch-deep” approach, whereby students had familiarity with a broad range of concepts, but the depth of their understanding of any given science concept was extremely limited (Porter, 2002; Southerland, Smith, Sowell, & Kittleson, 2007; Tanner & Allen, 2005). Rigor in the science classroom was based solely on the amount of disconnected knowledge a student had to know in order to pass a given test or science class (Pruitt, 2014). Moreover, while scientific inquiry was always included in state science standards, it was often overlooked in classrooms, curriculum, and student assessments (Trumbull, Scarano, & Bonney, 2006). Over the years, this then led to some educators viewing scientific inquiry more as a teaching method rather than as a way for students to connect what they had learned with how scientists worked (Capps & Crawford, 2013; Pruitt, 2014).

Combined, these concerns resulted in the call for new science content standards that fostered high quality teaching with improved curriculum, which resulted in the eventual release of the NGSS in 2013. The NGSS offers a vision of science and engineering learning in the classroom that makes science relevant and accessible for all students through the use of compelling questions, phenomena, and rich investigative learning experiences (National Research Council, 2015). In contrast to its predecessors, NGSS moves beyond past science instructional practices that primarily focused on memorization of facts, in favor of understanding and application (Allen & Penuel, 2014; Gallagher, 2000a; Pruitt, 2014). In its place, students will now be expected to use evidence and apply multidisciplinary concepts to real-world interconnections in science in order to demonstrate that they have a deeper understanding of the content (Pratt, 2013; Pruitt, 2014). The NGSS also emphasize the importance of providing all students with the opportunity to continuously build on and revise their knowledge and abilities throughout their K-12 schooling experience (National Research Council, 2015). The expectation is that, in doing so, more students and a more diverse group of students will want to continue their education in STEM-related fields (National Research Council, 2007) .

As a result of more states adopting the NGSS, many teachers are now facing the difficult task of understanding these new ideas, identifying how their current instructional practices align with the NGSS, and translating and implementing these new practices into their classrooms. Nonetheless, changing teacher instructional practices is not accomplished quickly or easily. For instance, because teachers bring a variety of knowledge, beliefs, and experiences to standards-based reform efforts, when educational change is required, they do not all respond the same way (Hargreaves, 2005). Some teachers support and sustain reform efforts, while others may feel "professional vulnerability" (Kelchtermans, 2005, p. 996) resulting in fear, frustration, and ultimately resistance (Datnow & Castellano, 2001; Hargreaves, 1998, 2005; Kelchtermans, 2005; Lasky, 2005; Schmidt & Datnow, 2005; van den Berg, 2002; Van Veen, Sleegers, & van de Ven, 2005). Teachers also cannot properly implement a curriculum reform that they do not completely understand (Gallagher, 2000b; McGee, Wang, & Polly, 2013; Powell & Anderson, 2002; Witz & Lee, 2009) For some teachers translating the NGSS into their practice may require interacting with new ideas, understandings, and real-life experiences where their knowledge is limited (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; Pruitt, 2014). Teachers also construct their understanding of standards-based reform efforts based on their personal beliefs (Spillane et al., 2002). As such, some teachers may find themselves implementing new instructional practices and policies that do not necessarily align to their own beliefs about teaching and learning (Johnson, 2007a, 2007b; Johnson, 2006; Loucks-Horsley & Matsumoto, 1999; Loucks-Horsley et al., 2010). For these reasons, as the implementation of the NGSS moves forward, it is imperative to examine teacher perceptions, beliefs, and knowledge related to this new reform effort.

Purpose of Study

The purpose of this study was to determine how school leaders, professional development providers, district curricular staff, and instructional coaches could better support teachers during this time of transition by examining (1) teacher perceptions and understandings of the NGSS, (2) how teachers are learning about the NGSS, (3) instructional shifts that are already occurring in the classroom and areas that may need additional support, and (4) factors teachers may consider critical to the implementation process.

Theoretical Framework

The theoretical framework for this research draws on sensemaking, which takes a cognitive approach to reform implementation. Research on sensemaking and policy interpretation suggests that individual implementers, such as teachers, must make sense of the explanations proposed by a new reform policy as well as the definitions of the problem implied by that policy (Spillane, 1998, 2000; Weick, 1995; Yanow, 1996). This work further suggests that sensemaking is situated not only in an organizational context, but also in the prior experiences and understandings of the individuals involved in the interpretation and implementation of a particular policy (Yanow, 1996). An individual's understanding of both the problems and solutions of a new policy are framed by who they are (identity) as well as by prior experiences and the cultural, organizational, and structural contexts in which they are situated (Drake, 2002).

In education, sensemaking theory examines teacher prior knowledge and experiences and how they shape, prioritize, and interpret policy messages (Coburn, 2001; Park & Datnow, 2009; Spillane et al., 2002; Weick, Sutcliffe, & Obstfeld, 2005). As such, teachers' experiences, attitudes, beliefs, and knowledge (i.e., cognitive structures) can enable or constrain their understanding and enactment of the NGSS in their own classrooms (Banilower et al., 2013). Yet, teacher cognitive structures are not static (Fullan, 2007). In fact, they are dynamic mental structures that can change according to experience and knowledge, thereby forming the foundation of enduring curricular reform (Fullan, 2007). Therefore, this study draws on sensemaking theory as a guide to exploring the intersection of teacher knowledge, beliefs, and interpretations of NGSS in an effort to gain a better understanding of how instructional shifts occur in the science classroom. While research does exist on teacher sensemaking in elementary and secondary schools relative to policy implementation, currently there is very little research on teacher sensemaking and the NGSS.

Research Questions

The study focused on how high school science teachers in two different districts were making sense of and responding to the NGSS. Throughout the study, the term "make sense" was used to refer to science teachers' knowledge, perception, assessment, beliefs, and experiences related to the implementation of the NGSS. Additionally, the term "respond" was used to refer to the ways in which teachers were transitioning their instructional practices to align with NGSS.

The combination of the researcher's personal experiences in science education, the current research on the NGSS, previous standards-based reform implementation, and the theoretical framework of sensemaking, helped to formulate the following research questions:

- What are the perceptions, beliefs, and knowledge of in-service high school science teachers about the Next Generation Science Standards (NGSS)?
- What types of professional development (if any) are teachers utilizing to help them understand and implement the NGSS?
- How (if at all) have teachers begun to shift their instructional practices to align with the vision of the NGSS? What areas need additional support?
- What factors are influencing teacher sense-making and implementation of the NGSS? What are some perceived barriers?

Overview of Methodology

With teacher sensemaking supporting the methodology, this study used a mixed-methods design, which is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative data during research to understand a research problem more completely (Creswell, 2012; Tashakkori & Teddlie, 1998). This mixed-methods design allowed the researcher to capture both quantitative data and rich qualitative descriptions that would not have otherwise been available by using one approach. Moreover, when used in combination, quantitative and qualitative methods complement each other and provide a more complete picture of the research problem (Creswell & Plano Clark, 2011; Greene, Caracelli, & Graham, 1989; Tashakori & Teddlie, 2010).

The first phase of the research design utilized a survey that included both closed and open-ended questions to capture qualitative and quantitative data about teacher knowledge, beliefs, instructional practices, professional development opportunities, and the school environment. The survey was administered utilizing a cross-sectional survey design. In a cross-sectional survey design, data is collected from a subgroup of the overall population in order to assess current attitudes, beliefs, opinions, or practices of other population members, in this case secondary science teachers (Creswell, 2012).

The second phase of the research design entailed semi-structured interviews focused on teacher knowledge, experiences, professional development, classroom practices, and school environment. The interview portion of the study was important because it provided a more in-depth look into how teachers are translating the NGSS into practice. The voices of the participants also provided a richer context to better explore teacher perceptions, implementation challenges, and the types of resources teachers are employing.

An integration of the quantitative and qualitative data took place as the final phase in the analysis. All patterns and findings from both phases of the study were connected and compared via the lens of the current literature in order to examine the common themes in the quantitative and qualitative methodologies (Creswell & Plano Clark, 2011). The goal of integrating the data through a mixed-methods approach was to provide the most in-depth understanding of the research questions and to add value and strength to the findings (Creswell & Plano Clark, 2011).

Significance of the Study

While the NGSS are a road map describing what all students should know and be able to do at the end of each grade level in the K-12 education system, it will take a well-prepared and well-supported teacher workforce in order to make the vision of the NGSS a reality. However, changing teacher practice does not happen overnight. Educational researchers who have studied teachers' responses to reform efforts have found that not only is there an inconsistency in alignment between state standards and teaching practices, but teachers either lack the ability or knowledge required to change their teaching practice to improve student outcomes (Gallagher, 2000a; McGee et al., 2013; Powell & Anderson, 2002; Witz & Lee, 2009). Moreover, some teachers just are not receptive to implementing education reform initiatives for a variety of reasons including lack of knowledge, personal beliefs, and pressures from their external environment (Abrami, Poulsen, & Chambers, 2004; Haag & Megowan, 2015). Therefore, findings from this study could contribute to the larger field of education by examining how teachers are constructing students' learning experiences in congruence with a new reform policy and/or how teachers themselves learn new ways of teaching.

Chapter 2: Literature Review

The focus of this study was to examine how teacher perceptions, beliefs, knowledge, and the school environment influenced their enactment of the NGSS. The following sections of this literature review utilize a wide range of research to further explain (1) the historical context of standards-based educational reform, (2) the development and adoption of the NGSS, (3) the conceptual shifts of the NGSS, and (4) the implementation process of reform policies and the critical role of teachers. In addition, this chapter explains the sensemaking theoretical framework used to guide this study and its connection to standards-based reform research. Understanding these key factors and practices will aide school leaders, practitioners, and policy makers in decisions related to science teacher professional development, curricular decisions, and teacher supervision.

Historical Context of the Next Generation Science Standards

To understand the relevance and potential implications for the NGSS, it is first important to briefly review the history of science education standards-based reform. Systemic standards-based reform, such as the NGSS, is based on the underlying principle that improved teaching and learning can be gained by creating "high-quality" content standards at the national or state levels (Darling-Hammond, 2004; DeBoer, 2000; Donnelly & Sadler, 2009; Duschl, 2008; Raizen, 1998; Roseman & Koppal, 2008). These reform efforts are often in response to a national "call for action" whereby the existing standards are viewed as inadequate for a variety of reasons. For example, the existing standards may no longer meet the current societal demands, changing student demographics, or new research about teaching and student learning (Duschl, 2008). In turn, this reevaluation often influences various aspects of the educational system including the creation and adoption of new standards. Moreover, once these new standards have been written and adopted, it is then up to the educational leaders to interpret and implement the reform policy's vision at the state, district, school site, and classroom levels; this often requires changes in curriculum, assessments, teacher development, and teaching practice (Fullan, 2016; Spillane et al., 2002).

The first major science reform occurred between the 1950s and 1970s and was sponsored by the newly formed National Science Foundation (NSF; DeBoer, 2000; Duschl, 2008; Reese, 2007). Similar to the NGSS, one of the main goals of this reform program was to produce K-12 science education programs that would get students to "think like scientists" (Rudolph, 2002). The second reform effort in science education began in the 1980s and continues to this day in some form as part of the national standards movement (Raizen, 1998). Referred as the Science for All movement, the educational goal was to develop a scientifically literate population that could participate in both the economic and democratic agendas of our increasingly global economy (Duschl, 2008; Raizen, 1998).

The Science for All movement originated in 1985 with the creation of Project 2061 by the American Association for the Advancement of Science (AAAS). With expert panels of scientists, mathematicians, and technologists, Project 2061 set out to identify what was important for students to know and be able to do in science, mathematics, and technology (American Association for the Advancement of Science [AAAS], 1993). The panels' recommendations were then integrated into Project 2061's 1989 publication, *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1993). *Science for All Americans* was built on the belief that scientifically literate people should have an understanding not only of the main concepts and principles of science, but also have the ability to use scientific knowledge and scientific ways of thinking for individual and societal purposes (Nelson, 1999; Raizen, 1998;

Roseman & Koppal, 2008; Rutherford & Ahlgren, 1990). Like the NGSS, *Science for All Americans* emphasized common themes and connections among ideas in the natural and social sciences, mathematics, and technology to enhance student learning (Roseman & Koppal, 2008). This document also included chapters on reforming education by promoting a core belief that all students should have access to high-quality science and mathematics instruction (Rutherford & Ahlgren, 1990).

While the philosophy behind *Science for All Americans* was sound, it was not without criticism. At the time most teachers lacked the training in math and science needed to carry out these changes (Spillane, 2005). In addition, new ideas about classroom practice and how students would achieve science knowledge and literacy were not well developed (Spillane, 2005; Tanner & Allen, 2002). Instead, teachers and teacher leaders were forced to interpret what the standards implied and then develop their own classroom curriculum (Raizen, 1998). In the end, interpretation of the standards led to the development and implementation of curriculum that was focused on student memorization of isolated facts and information for assessment purposes, which was counter to the document's core beliefs (Spillane, 2005).

With the growing dissatisfaction about *Science for All Americans*, Project 2061 published a new set of science guidelines, *Benchmarks for Science Literacy*, which were released in 1993 (*Benchmarks;* American Association for the Advancement of Science [AAAS], 1993). *Benchmarks* was a statement of expectations about what all students should know and be able to do in science, math, and technology. Unlike earlier standards, *Benchmarks* provided educators with suggestions on how to sequence various specific learning goals as they created new science curriculum (AAAS, 1993). Moreover, this publication was grounded in equity and asserted that science knowledge was essential for all students, not just future scientists and engineers (Tanner

& Allen, 2002). Towards this objective, *Benchmarks* endorsed an approach to science learning that was student-centered, rooted in engaging students' natural scientific curiosity and making science education relevant to the science of everyday living (AAAS, 1993; Banilower, Heck, & Weiss, 2007; Roseman & Koppal, 2008; Tanner & Allen, 2002). *Benchmarks* also presented for the first time a detailed outline of what students should know, understand, and be able to do during different stages of their K–12 experiences (AAAS, 1993).

Three years later, in 1996, using *Benchmarks* and *Science for All Americans* as supporting documents, the National Research Council published its own version of national science standards in the *National Science Education Standards* (NSES; National Research Council, 1996), which were based on the premise that "learning science is something that students do, not something that is done to them" (p. 2). These standards, written by teachers, scientists, and science educators, not only included standards for science content, but also provided guidance for teaching, teacher professional development, and assessments (Bianchini & Kelly, 2003). The NSES were widely popular and guided science education for over 10 years (National Research Council, 1996). However, one of the critiques of the NSES was the emphasis on a "mile-wide, inch-deep" approach. Students had familiarity with a broad range of concepts, but the depth of their understanding of any given science concept was extremely limited (Porter, 2002; Southerland, Sowell, & Enderle, 2011; Tanner & Allen, 2005). The NSES also perpetuated a separation of science core ideas from practice; current science education research indicates that practice and core ideas must be intertwined for students to engage more authentically in science (Bybee, 2012).

Despite their flaws, *Science for All Americans*, *Benchmarks*, and NSES together helped to shape our national vision of science educational standards and teaching practices. They also provided a foundation for the development of NGSS. The NSES and the *Benchmarks* promoted the "less is more" theory by stressing that students would have a deeper understanding and appreciation of science if they were allowed to explore scientific concepts and ideas more in-depth by covering fewer topics (Labov, 2006). All three documents contained some version of standards for technology and engineering and also situated inquiry in school science programs for the first time (Bybee, 2011; NGSS Lead States, 2013). More importantly, these documents recognized the importance and value of science literacy for all students in order to create a population that could participate in our increasingly global economy (Duschl, 2008; Raizen, 1998).

The Next Generation Science Standards

The United States is currently experiencing another science reform movement. With a growing need to produce a workforce with strong science, technology, engineering, and mathematics (STEM) backgrounds, declining student test scores in science and mathematics, and new research about science education and student learning, there has been a widespread call for a new approach to K-12 science education in the United States (Bybee, 2014; Kay, 2010; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; National Research Council, 2012; National Science Board, 2007; Trilling & Fadel, 2009). In response, in 2013 Achieve, an independent, nonpartisan, nonprofit education reform organization, released the *Next Generation Science Standards* (NGSS). In contrast to its predecessors, which focused on student memorization of facts, the NGSS emphasize classroom practices that produce real-life investigative learning experiences for students (Allen & Penuel, 2014; Gallagher, 2000b; Pruitt, 2014). The NGSS are also unique because they integrate multiple disciplines in science by connecting to the *Common Core State Standards* (CCSS) for English language arts, literacy and mathematics (Januszyk et al., 2016; Lee et al., 2014; NGSS Lead States, 2013). As such, the NGSS are expected to bring about fundamental changes in the K-12 science education system.

The NGSS were developed in a two-step process. The first step involved the development of the *Framework for K–12 Science Education* (Framework) by the National Research Council, which was released in 2011. The Framework was a critical first step because it was grounded in the most current research on science and science learning, and it identified the science that all K–12 students should know. The second step in the process was Achieve's development of new science standards based on the content in the National Research Council's Framework (NGSS Lead States, 2013). Science teachers, scientists, engineers, employers, and educational leaders from 26 different states provided feedback on drafts of the NGSS (NGSS Lead States, 2013). These drafts underwent multiple reviews and provided individuals and interested groups with an opportunity to provide feedback (Bybee, 2014; NGSS Lead States, 2013). From this process, a set of K-12 learning standards which contained concise written descriptions of what students were expected to know and be able to do at each grade level were created (NGSS Lead States, 2013).

Since the NGSS is a policy document, and not a mandated set of federal or national standards, each state had the freedom to decide whether or not to adopt the NGSS as the state's science standards. As of November 2017, 19 states, along with the District of Columbia (D.C.), have adopted the NGSS, representing over 35% of the students in the United States (NGSS Lead States, 2013). California, the state in which this study occurred, adopted the NGSS on September 2, 2013 (California Department of Education, 2014).

In response to the NGSS, California also developed and adopted a new state science framework. In November 2016, the California State Board of Education adopted the *Science Framework for California Schools: Kindergarten Through Grade Twelve.* The purpose of this framework was to provide school districts in California implementation guidelines around curriculum, instruction, and teacher development connected to the NGSS (California Department of Education, 2014).

California is also in the process of adopting a new science assessment titled the California Science Test (CAST). In the spring of 2017, the CAST was piloted to grades five, eight, and grades 10 through 12. In the 2017-2018 school year, the CAST will be field tested again, and in the 2018-2019 school year, state officials expect to have a fully operational test. The adoption of the NGSS, the *Science Framework for California Schools*, and the CAST completed the initial steps of systemic standards-based reform in California. The next steps will involve the task of translating the NGSS to school curriculum and classroom instruction (Bybee, 2013).

Conceptual Shifts of the Next Generation Science Standards

This section examines some of the key instructional and conceptual shifts that teachers will need to make sense of in order to translate and implement the NGSS with fidelity and consistency. The intent is not to undertake a comprehensive review of all the changes outlined in the Framework and the NGSS, but rather to examine in more detail areas that are significantly different from former standards. Key areas that will be reviewed include: three dimensional learning; performance expectations; integration of science and engineering practices; and NGSS-aligned instructional practices. Information was based on content from *A Framework for K-12 Science Education* (National Research Council, 2012), *Appendices* in NGSS (NGSS Lead States, 2013), *Guide to Implementing the Next Generation Science Standards (*National Research

Council, 2015), and *Introducing Teachers and Administrators to the NGSS: A Professional Development Facilitator's Guide* (Brunsell, Kneser, & Niemi, 2014).

Three-dimensional learning. Perhaps the most significant feature of the NGSS is the vision that the three dimensions, Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts, should be presented simultaneously in the science classroom. This kind of learning is referred to as three-dimensional or 3-D learning. Three-dimensional learning is based on research that clearly shows that learning science content cannot be separated from the doing of science (Krajcik, 2015). Therefore, in order for students in the K-12 educations system to learn science content, they must use the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts together. None of the dimensions can be used in isolation; they work together so that students can build deeper understanding as they grapple with making sense of phenomena or finding solutions to problems (Bybee, 2014; National Research Council, 2015; Krajcik, Codere, Dahsah, Bayer, & Mun, 2014; NGSS Lead States, 2013; Pruitt, 2014). This is a conceptual shift from most state and district standards, which often emphasized science content over skills (Bybee 2014; Brunsell et al., 2014). Additionally, by interweaving the three dimensions in science learning, it is anticipated that students will be better prepared for a role in the competitive global economy (Brunsell et al., 2014; Krajcik et al., 2014).

Dimension 1: Science and engineering practices. There are eight Science and Engineering Practices the Framework identified as essential for all students to learn in detail (see Appendix A). The National Research Council (2012) used the term “practices” instead of “skills” to emphasize that engaging in scientific investigation requires not only skill, but also knowledge that is specific to each practice. The National Research Council’s intent was to better explain and extend what is meant by “inquiry” in science and the range of cognitive, social, and physical practices that is required. Students will now be expected to (a) define problems by specifying criteria and constraints for acceptable solutions; (b) generate and evaluate multiple solutions; (c) build and test prototypes; and (d) augment a solution (Bybee, 2011; National Research Council, 2015). Engagement in the science and engineering practices is also deemed important because it represents the same behaviors that scientists and engineers use in the real world, hopefully making the process more relevant and meaningful for students (National Research Council, 2015).

Dimension 2: Crosscutting concepts. The Framework outlined seven Crosscutting Concepts or themes that applied across all scientific disciplines. The purpose of the Crosscutting Concepts was to provide students with an organizational framework to connect ideas from engineering, physical, life and earth/space sciences (Duschl & Grandy, 2013; National Research Council, 2012). For example, students will now be able to see how energy and matter are essential to understanding not only life sciences, but also physical science, earth science, and engineering.

Dimension 3: Disciplinary core ideas. Disciplinary Core Ideas are grouped into four domains: Life Science; Earth and Space Sciences; Physical Science; and Engineering, Technology, and Applications of Science. The purpose of the Disciplinary Core Ideas was not only to facilitate and accommodate instruction, which allows for a deeper understanding and application of content, but to also represent what all students should know by the time they graduate from high school (Pratt, 2013). Toward this objective, the Disciplinary Core Ideas build coherently across multiple grades and connect between the life, physical, earth and space sciences, along with engineering (National Research Council, 2015). As a result, learning sequences within and between grades must be designed with coherence in mind to guarantee that all students have multiple opportunities to interact with the key Disciplinary Core Ideas (National Research Council, 2015).

Performance expectations. Instead of traditional assessments, the NGSS emphasize classroom-based assessments in the form of student performance expectations (PEs). PEs describe what students should know and be able to do by the end of each grade level or course (Bybee, 2013). Earlier science standards listed what students should know or understand and then teachers translated these ideas into student performances that could be assessed to determine whether or not students met the standard (NGSS Lead States, 2013; National Research Council, 2012). However, different interpretations sometimes resulted in assessments that were not aligned with the curriculum and instruction (NGSS Lead States, 2013). The NGSS have tried to avoid this difficulty by developing PEs that clearly articulate what students should be able to do in order to demonstrate mastery (NGSS Lead States, 2013; National Research Council, 2012). Each PE incorporates all three dimensions from the Framework. This design is intended to better help students fully grasp and understand at a deeper level the scientific concepts and ideas (Krajcik et al., 2014; National Research Council, 2007, 2012).

Prior to the NGSS, science education only used inquiry or laboratory investigations as a way to reinforce content that students were learning in class (Bybee, 2013; Krajcik et al., 2014). However, recent studies have shown that students who engage in inquiry-based activities, which include the three dimensions of learning, can learn the content and ideas on their own (Bybee, 2013; Krajcik et al., 2014; National Research Council, 2012). To support this process, the Framework structured the PEs so they blend the three dimensions together in a way that students can now demonstrate what they have learned or mastered in a variety of response formats, such as supplying an answer, producing a specific product, or performing an activity (Bybee, 2013; Krajcik et al., 2014; National Research Council, 2012; NGSS Lead States, 2013).

An example of a PE for high school life science is located within Appendix B. As illustrated, the standards are organized in a table format with three main sections: (a) performance expectation(s); (b) foundation boxes; and (c) connection boxes. Each set of performance expectations has a title. Below the title is a box containing the performance expectations, and three foundation boxes that list (from left to right) the specific science and engineering practices, core disciplinary ideas, and crosscutting concepts that were combined to produce the PEs. The bottom section lists connections to PEs in other science disciplines at the same grade level, PEs of the same core idea for younger and older students, and related Common Core State Standards in mathematics and language arts. Teachers who are implementing curriculum and instruction that is consistent with NGSS should require student performances that integrate these dimensions and include multiple opportunities to interact with the material (National Research Council, 2015). In the classroom, students producing work such as models, writing, and other products that reveal student thinking will demonstrate this practice (National Research Council, 2015).

It is important to point out here that implementing the PEs will be challenging. First, PEs are not instructional units, lessons, activities, or even actual tests (Bybee, 2013; Krajcik et al., 2014; NGSS Lead States, 2013; National Research Council, 2012). Instead, PEs are a set of learning outcomes illustrating the competencies students should develop as a result of classroom instruction (Krajcik et al., 2014). Therefore, the challenge for school districts, science departments, and individual classroom teachers will be in translating these performance expectations into an instructional sequence that will provide adequate opportunities for students to learn the content of the standard (Krajcik et al., 2014). Second, at present, most assessments focus on student learning of discrete information and facts (National Research Council, 2012). However, to successfully implement and assess student learning consistent with the PEs, teachers will need to change how they assess and assign grades. Teachers will now need to develop tasks that measure student progress toward mastery of the skills and content, and then come up with some way to assign student grades (National Research Council, 2015).

Integration of science and engineering practices. For the first time, a strong emphasis is being placed on adding science and engineering design into K-12 classrooms. As such, it is important to highlight some of the main arguments as to why it is beneficial to student learning. First, science and engineering practices promote a way of thinking that can help with the development of skills and knowledge necessary for the 21st century (Bybee, 2011; National Research Council, 2012). While science and engineering both involve the analysis and interpretation of data, students at all grade levels will now be required to use and apply evidence to formulate a logically coherent explanation of phenomena and to support a proposed solution for an engineering problem (Bybee, 2011; Krajcik & Merritt, 2012; Krajcik et al., 2014).

Second, students who engage with science and engineering skills in their science classrooms will increase their chances of having the necessary skills required for the future workforce. Employability in today’s society increasingly depends on having broad capabilities in 21st-century skills such as the ability to solve unfamiliar or unexpected problems, work in teams, or respond to changing circumstances (Bybee, 2011; Lee et al., 2014; Moore, Tank, Glancy, & Kersten, 2015). The development of these skills can be supported in the science classroom when instruction is designed to engage students in doing science rather than just hearing about it (Moore et al., 2014).

However, even with the increasing demands in the United States for science and engineering skills and practices, several researchers pointed out barriers to the integration of these two ideas within the K-12 system. Bybee (2014) argued that teachers in the K-12 setting lack an understanding of engineering practices and do not understand the differences between scientific practices and engineering design. This opinion was reinforced in a study by Haag and Megowan (2015) in which teachers expressed concerns about their lack of an engineering background and the need for more training to better understand engineering in the context of science as intended by NGSS. Coffey and Alberts (2013) reported some teachers felt engineering practices meant more content, and as such did not need to be taught.

Shifts in classroom practices. For most teachers, the new vision for science education as described in the NGSS represents a major change from current instructional practice. Current or "traditional" practices place an importance on a more teacher-centered classroom where the teacher delivers the content through the use of textbooks, lectures, and scientific facts (Roehrig & Kruse, 2005; Secker, 2002). Whereas in a classroom aligned to the new vision of science education will require students to be more responsible for their own learning as illustrated in Table 1, adapted from the *National Research Council*'s *Guide to Implementing the Next Generation Science Standards* (2015, p. 11). In this type of classroom environment the teacher becomes more of a facilitator who is responsible for creating structures and supports within the classroom so students can work productively and learn from their peers while working in pairs, groups, or as a whole class (Driver, Newton, & Osborne, 2000; Jones, 2007; National Research Council, 2015). The teacher would also be responsible for guiding student conversations and learning through purposeful questioning and feedback so students can actively engage in scientific discourse in order to deepen individual and collective understanding of the concepts and ideas (Lyon et al., 2016; National Research Council, 2015; Tolbert, Stoddart, Lyon, & Solis, 2014).

Table 1: Conceptual Shifts of the Next Generation Science Standards

Science Education Will Involve Less:	Science Education Will Involve More:
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning
Learning of ideas disconnected from questions about phenomena	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned
Teachers providing information to the whole class	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance
Teachers posing questions with only one right answer	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims
Students reading textbooks and answering questions at the end of the chapter	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information
Pre-planned outcome for the "cookbook" laboratories and hands-on activities	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas
Worksheets	Students writing of journals, reports, posters, and media presentations that explain and argue
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

Note. Implications of the vision of the *Framework* and NGSS. Adapted from *Guide to Implementing the Next Generation Science Standards* (National Research Council, 2015, p. 11).

Similarly, students may struggle because up to this point for some of them their school experiences may have consisted of memorizing and reproducing facts provided to them by their teachers or textbooks, instead of being actively involved with their learning (National Research Council, 2015; Powell & Anderson, 2002; Tanner & Allen, 2005). Thus, the process may be uncomfortable at first as some teachers and students slip back into old habits in which the students wait to be told the information and the teacher delivers the information or answers to them (National Research Council, 2015). As a result, to successfully implement the vision of the NGSS, it will be important for educational leaders at all levels to be aware of some of the possible pitfalls beforehand so they can proactively be addressed.

Education Reform Implementation and Teachers

With the recent adoption of the NGSS, many school districts are now facing the difficult task of effectively implementing these new objectives. Implementation is what "takes place between the formal enactment of a program by a legislative body and its intended or unintended impacts" (Porter, Fusarelli, & Fusarelli, 2015, p. 114). During the first wave of implementation, analysts identified the problem of policy implementation as a result of an unclear relationship between the policy message and what was enacted at the school district and school site levels, which in turn lead to incoherence and misalignment (Mclaughlin, 1987; McLaughlin & Shepard, 1995). Findings from these research efforts led to the assumption that external or "outside-in" alignment of standards, curriculum, and assessments at the state level could help reduce incoherence and misalignment (Coburn, 2005b; Mclaughlin, 1987; Smith & O'Day, 1990; Werts et al., 2013). These early analyses established what has been called the "implementation perspective" and laid the groundwork for subsequent implementation analyses (Mclaughlin, 1987, p. 172)

During the second wave of implementation, analysts focused more on how policy was enacted at the local level. This approach, unlike the first wave, promoted coherence and alignment from the "inside-out" by engaging school leaders to set their own goals and improvement strategies that better fit their local circumstances (Coburn, 2005b; Honig & Hatch, 2004; Mclaughlin, 1987; Werts et al., 2013). Implementation was then viewed as a process of mutual adaptation at all levels of the system, which arose from "loose coupling" between elements of the educational system (Coburn & Talbert, 2006; Desimone & Smith, 2007; Marx & Harris, 2006; Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, 2009; Weick et al., 2005). As a result, educators at all levels of the school system, all with at least some autonomy in their day-to-day activities, had to work together in order to implement the new reform policy successfully (Coburn, 2013). This process promoted ongoing local sensemaking about relationships among external policy demands and the needs of the school sites (Honig & Hatch, 2004).

Following the outside-in and inside-out implementation approaches of the past, for the third wave of implementation analysts focused on how teacher interpretations of policy were shaped by their environment. Using this lens, implementation was viewed from the teacher perspective and they placed new information into their framework of experiences, attitudes, beliefs, knowledge, and school environment, in order to construct meaning (Coburn, 2001, 2005a; Spillane et al., 2002; Spillane & Zeuli, 1999). Vaughan (1997) argued this process not only gave meaning to new information for teachers, but also allowed them to focus and adapt information so that it was manageable. For once successful policy implementation was seen as being innately linked to teachers' perceptions or understandings, including their beliefs, intentions, attitudes, emotions, and knowledge (Czerniak & Lumpe, 1996; Haney & Lumpe, 1995; Lumpe, Haney, & Czerniak, 2000). These finding directed the practice used today of using teacher professional development to expand teacher perceptions and understandings of the new reform message (Darling-Hammond, 2004).

However, researchers have pointed out that changing instructional practices and beliefs pertaining to student learning represents a difficult and challenging task for teachers. Teacher ideas about subject matter, student ability, and their instructional practice do not change easily or rapidly (Van Driel, Beijaard, & Verloop, 2001). As such, issues of teacher change should be central to any discussion about standards-based reform implementation. In general, when teachers are asked to implement new instructional practices, some degree of change is required along any or all of the following dimensions: (a) beliefs, attitudes, or pedagogical ideologies; (b) content knowledge; (c) pedagogical knowledge of instructional practices, strategies, methods, or approaches; and (d) novel or altered instructional resources, technology, or materials (Fullan, 2016). When thinking about implementing new reform efforts, such as NGSS, it is important to take a closer look at change through the lens of the individual as an agent of change and how individuals respond to the message (Ertmer & Ottenbreit-Leftwich, 2010; Johnson, 2006; Lee, 2004; Spillane et al., 2002). In reviewing the literature about teachers and factors that influence teacher responses to reform efforts, five broad categories were found that related to the study and are examined in more detail. These categories include: (a) teacher knowledge; (b) teacher beliefs; (c) teacher emotions; (d) school environment; and (e) professional development.

Teacher knowledge. Studies that examined science teacher responses to reform efforts stress the importance of teacher knowledge. While there is not a single definition of teacher knowledge due to the complex nature of teaching, historically, teacher knowledge has been conceptualized using the framework proposed by Shulman (1986, 1987). According to Shulman (1986), teacher knowledge can be categorized into three types: (a) subject matter content knowledge; (b) curricular knowledge; and (c) pedagogical content knowledge. Subject matter content knowledge is what teachers know about a particular subject and curricular knowledge is the knowledge teachers have about the materials available to teach that subject (Shulman, 1986). The last category, which has become the most prominent in educational research, pedagogical content knowledge (PCK), is described as the ability to take different kinds of knowledge such as content, pedagogy, and context and transform it into meaningful instruction whereby students can successfully learn (Abell, 2008; Shulman, 1986). This includes knowing which ideas build on each other and what prior conceptions students might bring to the classroom (Shulman, 1987). Researchers also agree that PCK is not just something teachers possess; it is a tool that they use in planning and carrying out instruction (Van Driel, Bulte, & Verloop, 2007).

Teacher beliefs. The identification of teacher beliefs is considered to be critical to the science education reform process. Teacher beliefs are seen as a key factor in changing and sustaining instructional practices and classroom culture (Borko & Shavelson, 1990; Fullan, 2016; Krajcik, Blumenfeld, Marx, & Soloway, 1994; Loucks-Horsley & Matsumoto, 1999; Powell & Anderson, 2002; Van Driel et al., 2001). Teacher beliefs have been described as their convictions, philosophy, tenets, or opinions about academic content, students' abilities to learn academic content, the role of language and culture in instruction, the teachers' own self-efficacy, modifications in teaching practices, as well as the role of the teacher in the classroom (Lee, 2004; Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012). Both prospective and in-service teachers develop their beliefs about teaching from the years spent in the classroom as both students and teachers (Milner et al., 2012). As a result, teachers form fundamental beliefs over time through active engagement with ideas, understandings, and real-life experiences (Loucks-Horsley et al., 2010). Through this lens, internalizing and putting the ideas of NGSS into practice may be difficult for some teachers due to entrenched ideas and beliefs around old teaching habits that may be incompatible with the vision of the NGSS (Czerniak & Lumpe, 1996; Levitt, 2002;

Zembylas, 2003). These incompatible beliefs could then result in a gap or lack of coherence between the intended principles of reform and what is actually implemented in the classroom, potentially limiting educational change (Levitt, 2002).

Teacher beliefs also have a strong connection to their actions, which in turn, can lead to the development of specific attitudes that may be in opposition to the NGSS. Empirical studies have demonstrated that teacher beliefs are (a) stable and resistant to change; (b) act as a filter through which they interpret teaching events; and (c) shape the nature of instruction the teacher provides to students (Czerniak & Lumpe, 1996; Haney & Lumpe, 1995; Lumpe et al., 2000). As such, a teacher's beliefs about science, learning, and science teaching, influence almost every aspect of their teaching practice because beliefs serve as a filter through which actions are viewed and decisions are made (Sampson & Grooms, 2013). The connections among clusters of beliefs then create an individual's values that guide one's life and ultimately determine behavior (Ajzen, 1989; Pajares, 1992). Pajares (1992) explained that clusters of beliefs around a particular situation will form attitudes, and these attitudes then become action agendas that guide decisions and behaviors. In other words, people act upon what they believe.

There is also a growing concern about teacher beliefs about students and the ever-changing landscape of the classrooms in the United States. For example, the percentage of White students in public schools is declining as the enrollment of Hispanic students have increased (Jackson & Ash, 2012; Lyon et al., 2016; National Center for Education Statistics [NCES], 2016). Students who are English Language Learners (ELLs) also make up the fastest-growing student population in public schools (Jackson & Ash, 2012; NCES, 2016). However, about 88% of teachers in the United States are White (Flores, 2007). This is problematic because teachers may have a preconceived belief system that ELL students negatively impact their classroom learning environment instead of adding enrichment (Blanchard & Muller, 2015; Flores, 2007). Moreover, science curriculum, materials, and instruction in the United States overwhelmingly have reinforced the traditional view of science as an area for predominantly White males (Johnson & Bolshakova, 2015). As a result, science instruction in the K-12 setting has been void of classroom instructional practices and curriculum resources that integrate an array of student backgrounds (Johnson & Bolshakova, 2015).

Teacher emotions. Researchers have acknowledged that teacher emotions also play a large part in policy implementation because “emotions are at the heart of teaching” (Hargreaves, 1998, p. 835). An emotional response towards change is defined as the way an individual perceives, interprets, and evaluates one’s relationship with the changing environment (Zembylas, 2003). In the past, teacher resistance to change was often attributed to stubbornness, lack of imagination, and laziness (Fullan, 2016). But in reality, a teacher’s resistance to reform efforts and change was often related to their emotions about the change (Hargreaves, 1998, 2004, 2005; Schmidt & Datnow, 2005; Van Veen et al., 2005). For instance, teachers could have feelings of fear about how the reform effort will affect their relationships with students and colleagues due to them feeling overwhelmed by the new demands and lack of control in their own classroom (Hargreaves, 1998, 2004, 2005; Nias, 1996; van den Berg, 2002). This, in turn, often results in teachers resisting the implementation of the new policy when it is perceived that the new practices will not match the reality of what occurs every day in their classroom or school (Schmidt & Datnow, 2005). However, emotional disappointment with reform efforts is not only a byproduct of the new demands teachers feel are being placed on them, but rather the accumulative effects of the repetitive and inconsistent nature of such demands (Kelchtermans, 2005). It is not surprising, then, that attempts for science education change envisioned in the

Framework and carried out in the NGSS may hinge on teacher perceptions and feelings about this new reform effort.

School environment. Research related to standards-based reform implementation have suggested that school-related factors have a significant impact on a teachers' ability to change their practice (Coburn, Mata, & Choi, 2013; Honig & Hatch, 2004; Porter et al., 2015). These factors include but are not limited to: the level of administrative support; classroom space; availability of curriculum materials; funding; and collaborative time devoted to planning and teaching (Banilower et al., 2007; Louis, Febey, & Schroeder, 2005; McLaughlin & Shepard, 1995). Moreover, the extent to which a teacher feels they can implement a high quality science curriculum may be contingent on their school demographics and perceptions about student abilities (Coburn, 2005b). As a result, this interrelationship between school environment and teacher practice causes standard implementation to look different from school to school and classroom to classroom.

Professional development. Professional development is seen as an integral feature of school reform because it is the primary tool that schools, districts, and states use to support teacher learning during the implementation of new standards-based reform efforts (Guskey, 2010; Loucks-Horsley et al., 2010; Paik et al., 2011). Professional development is not only used to enhance teacher knowledge and skills, but also as a vehicle to improve teacher attitudes about the new policy (Darling-Hammond, 2010). However, Reiser (2013) stressed a need for a change in how school districts design and conduct teacher professional learning (Guskey, 2010; Paik et al., 2011; Reiser, 2013). This opinion is based on reports from teachers about their professional development experiences. Teachers cited professional development opportunities were often brief "one-shot" workshops that focused on a specific instructional practice connected to a specific lesson, rather than helping them to build a repertoire of instructional strategies (Hill, 2007; Reiser; 2013). As Hill (2007) noted, "[b]y all accounts, professional development in the United States consists of a hodgepodge of providers, formats, philosophies, and content" (p. 114). Studies have also reported that even though a large amount of money in the K-12 school system is spent on teacher professional development aimed at learning new standards, content, and practices, in reality many teachers never change their own approach to teaching and learning (Banilower et al., 2007; Darling-Hammond & McLaughlin, 1995; Firestone, Mangin, Martinez, & Polovsky, 2005; Mclaughlin, 1987). Moreover, the majority of the programs fail because they do not take into account what motivates teachers to engage in the professional development and do not take into consideration the process of teacher change (Guskey, 2010). As such, professional development in the United States often does not currently reflect an environment where true teacher learning can regularly occur.

There are specific components of professional learning that can prompt teachers to change their classroom practice. Despite the many challenges associated with teacher professional development, studies of various programs reveal an emerging consensus about those features that are most promising for supporting teacher learning (Borko, 2004; Phillips, Desimone, & Smith, 2011; Wilson, 2013). Reiser (2013) summarized four key features that are necessary to support teacher learning:

- professional development should be embedded in subject matter;
- professional development needs to involve active learning;
- professional development needs to be connected to teachers' own practice; and
- professional development needs to be a part of a coherent system of support.

These practices are important because supporting students in the type of coherent sensemaking science practices called for in the NGSS will require a change in teachers' daily practices. As a result, school districts and school sites should continually assess and think about each one of these elements and ensure they are incorporated into their teacher professional development in order to provide effective support and learning environments for teachers as they begin to make sense of the NGSS.

Theoretical Framework

In this study, the researcher utilized a sensemaking theoretical framework to guide the research design and interpretation of the findings. The theoretical framework of sensemaking is based on understanding the ways in which the social and cultural structure of organizations develop and change over time (Coburn, 2004). Sensemaking originates from organizational science research, and hypothesizes that when individuals encounter situations or knowledge different from their current state of understanding, they engage in a process that involves organizing, interpreting, and "making sense" of this new information (Weick et al., 2005).

An individual's sensemaking process does not occur in isolation. Rather, it relies on an individual's previous knowledge, beliefs, and experiences that can change depending on the message (Weick, 1995). Thus, the sensemaking process is not only the result of individuals' preexisting worldviews, but also of the interpretation of the their surrounding environment (Coburn, 2001). Individuals participate in this process by placing new information into their framework of experiences, attitudes, beliefs, knowledge, and environment in order to construct meaning from the new message (Coburn, 2001, 2005a; Spillane et al., 2002; Spillane & Zeuli, 1999). From this perspective, individuals intuitively understand new messages in different ways and not necessarily in alignment with the original message, creating opportunities for both misunderstandings and rebuilding of existing knowledge (Spillane, 2005). Consequently, when confronted with a new message, interpretations of it will determine whether the individual engages in significant change, incremental change, or resistance (Gold, 2002; Louis & Dentler, 1988). This is an important point to understand because change in organizations can be slow and tedious (Weick et al., 2005). It is not necessarily that individuals within an organization have an attachment to the status quo, or lack the capacity to change; rather, the change needs to be filtered through their sensemaking process (Spillane et al., 2002).

Sensemaking does not refer solely to individual processes either; rather, it is social in nature. First, sensemaking is collective in that it is rooted in social interactions and negotiations (Coburn, 2001; Louis et al., 2005; Porac, Thomas, & Baden-Fuller, 1989; Trice & Beyer, 1993; Weick, 1995). Meaning, people make sense of messages within their organization through conversation and interactions with their colleagues. These conversations and interactions then lead to shared ways of thinking that can be translated into common actions (Coburn, 2001). Second, sensemaking is social in the sense that it is rooted in an individual's immediate environment (Coburn, 2001). When an individual or group is trying to make sense of a message, they draw on ideas and approaches from the community or organization in which they reside (Coburn, 2001). Norms and routines of organizational subunits, such as department or workgroup organizational values and traditions, and the broader professional culture, all provide another lens for making sense of a new message, and in turn, shape priorities and actions (Porac et al., 1989; Spillane, 1998; Weick, 1995; Yanow, 1996).

Sensemaking and education. In educational settings, sensemaking theory has been used to unpack and account for educators' understandings and responses to policy, such as the NGSS. Drawing on sociological theories of sensemaking, researchers have argued that how teachers come to understand and enact instructional policy is influenced not only by their prior knowledge and beliefs, but also by the social context in which they work, and the nature of their connections to the policy or reform message (Spillane et al., 2002; Spillane, Reiser, & Gomez, 2006). In evaluating the implementation of policy, conventional research assumes implementers lack an understanding of the policy, or the policy itself is ambiguous and as a result fails (Spillane et al., 2002). Through the lens of sensemaking, an alternative explanation stresses the influence of implementers' sensemaking processes on policy implementation and its success or failure (Coburn, 2001; Park & Datnow, 2009; Spillane et al., 2002).

Sensemaking theorists argue that examining policy implementation at the classroom level through the lens of sensemaking can provide the "missing link" for how change gets enacted in schools (Palmer & Snodgrass Rangel, 2010). In this respect, the school and classroom culture, structure, and routines would be a result of "micro-momentary actions" by teachers and others in the school (Porac et al., 1989). These actions are then based on how people notice or select information from the environment, make meaning of that information, and then act on those interpretations (Porac et al., 1989; Weick, 1995). In turn, these actions create incremental changes that can lead to new classroom and school cultures, social structures, and routines, which over time ultimately affect student learning and achievement.

Yet, change within the education system does not always transpire or occur as expected. Educational researchers who draw upon the sensemaking framework have identified several barriers to effective implementation of policy (Coburn, 2001; Park & Datnow, 2009; Spillane & Zeuli, 1999). For instance, there is a mutual dependence between policy and implementers (Coburn, 2001). Once a new policy is created, implementers at various levels in the system, through their own sensemaking processes, are simultaneously forming policy and executing it, based on their understandings and beliefs, and then passing along the message (Coburn, 2001; Park & Datnow, 2009). Spillane et al. (2002) outlined a cognitive framework of sensemaking that illuminated this process. The framework consisted of the intersection of internal and external factors and how they influence policy implementation in education.

In an educational setting, one of the external factors that influence teacher sensemaking processes is how information about the reform policy is disseminated. For instance, district personnel receive multiple external policies that are then translated and distributed into manageable forms to the school sites and the teachers (Coburn, 2005a, 2005b; Spillane et al., 2002). However, before disseminating the message to the school sites, a process referred to as "simplification" occurs (Honig & Hatch, 2004). Through the process of simplification, administrators will often draw upon "scripts," or a set of identities and appropriate responses to communicate policy messages, which in turn result in the policy being "bridged" or "buffered" by the individual's own experience and sensemaking processes (Honig & Hatch, 2004, p. 23). In fact, when bridging policy messages, district personnel often connect new policy messages to existing practice (Spillane & Callahan, 1999). These individuals may also choose to "buffer" or deprioritize messages as a means to protect schools from increasing external demands (Honig & Hatch, 2004). School leaders may also overemphasize aspects of policy based on more influential voices or external pressures (Coburn, 2001). Therefore, leadership at the district level is important because those individuals ultimately mediate what gets communicated to the school sites by focusing on certain messages over others and structuring time to meet and collaborate about the particular message (Coburn, 2005a; Jennings, 2010).

The principal also occupies a unique structural position in that s/he monitors school progress, acts as the primary point of contact between the school site and the district, and uses this information to develop the focus of the school (Jennings, 2010). Principals, like teachers, tend to link new policy with prior understandings and organize teacher learning opportunities and social interactions accordingly (Spillane et al., 2002). Therefore, policies can be implemented differently based on the principal's interpretation (Coburn, 2005a; Jennings, 2010). School site leadership can also indirectly influence how information about reform messages are disseminated by arranging physical spaces such that teachers interact with some colleagues with greater frequency than others (Coburn et al., 2013). School site dynamics between the principal and the teachers can also factor into policy implementation (Van Veen et al., 2005). Teachers who lack faith in leadership are less likely to change instructional practice (Spillane & Callahan, 1999). Hence, site administrators play a key role in the language used and how the policy message is communicated to teachers (Coburn, 2001; Honig & Hatch, 2004; Spillane & Callahan, 1999).

To minimize this process, Honig and Hatch (2004) stated school sites should create distributed leadership structures to more effectively make sense of and communicate policy reform. Under this model, schools could then set their own goals consistent with their individual culture and needs, and then use these goals as a mechanism to determine whether the new policy message should be expanded (bridged) or minimized (buffered) (Honig & Hatch, 2004). In this way, site administrators and district leadership personnel negotiate the fit between external demands and the goals of the school sites. Once the school's goals have been established, the principal's leadership, along with peer influence, could affect teachers' instructional practice and students' performance (Supovitz, Sirinides, & May, 2010).

Internal factors, such as a teacher's personal experience, beliefs, history, and culture, could also influence how they make sense of a new reform policy. Teachers link their new messages to their prior knowledge or belief systems, then frame and reframe messages until they arrive at a new understanding, a process Spillane and Callahan (1999) refer to as the "zone of enactment" (p. 144). Since different teachers bring different knowledge, beliefs, and experiences to new policies, independently they form ideas about what the new policy represents for their own teaching, in turn causing the individual to pursue a different course of action than their peers (Coburn, 2001; Spillane & Zeuli, 1999). For example, some teachers may interpret the new policy as something they are already doing and not see the need to change their instructional practice (Coburn, 2001; Spillane et al., 2006; Spillane & Zeuli, 1999). Others may find parts of the new policy expectations either too difficult, developmentally inappropriate for students, or unmanageable, and only implement the elements they deem necessary or appropriate (Coburn, 2001). Teachers may also form different interpretations of the same message depending on their professional communities and collaborative conversations (Coburn, 2001). In the end, depending on how the teacher makes sense of the message, these individual sensemaking processes could produce incoherent policy implementation that is not consistent with the original intent of the policy (Park & Datnow, 2009).

In sum, teacher learning is influenced by opportunities and personal knowledge or beliefs that may contrast with reform messages and may potentially limit change within the education system. Sensemaking factors into all levels of the broader educational system and includes district leadership and personnel, site administrators, and individual teachers. Each of these organizational actors construct "the demands of, and appropriate responses to, accountability systems differently" (Jennings, 2010, p. 229). These differences can then lead to variations in how educational policies are implemented.

Chapter Summary

Policy makers have made considerable efforts in the past to improve public education with standards-based reforms. Although many of standards-based reforms that emerged since the late 1980s were primarily focused on content and skill-based instructional goals, they highlighted the need to raise academic rigor in science classrooms and increase student engagement (Blum, 2000; Diamond & Spillane, 2004; Spillane, 2012). Following in this tradition, the NGSS also aim to improve the academic rigor in science classrooms by emphasizing learning in three dimensions: The Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas (NGSS Lead States, 2013). As a result, many teachers are now facing the difficult task of understanding these new ideas, identifying how their current instructional practices align with the NGSS, and translating and implementing these new practices into their classrooms. Thus, educational leaders need to consider how to better support their teachers during this time of change.

Chapter 3: Methodology

This chapter presents the methodology used to describe the experiences of high school science teachers as they begin the difficult task of understanding the ideas presented in the NGSS and translating and implementing these new practices into their classrooms. Included in this chapter are the research questions that guided the study and an overview of the research design. In addition, participant recruitment, data collection, instrumentation, and data analysis methods will be described.

Research Questions

The purpose of this study was to determine how school leaders, professional development providers, district curricular staff, and instructional coaches could better support teachers during this transition time by examining: (1) teacher perceptions and understandings of the NGSS; (2) how teachers are learning about the NGSS; (3) instructional shifts that are already occurring in the classroom and areas that may need additional support; and (4) factors teachers may consider critical to the implementation process. The current research on the NGSS, previous standards-based reform implementation, and the theoretical framework of sensemaking helped to formulate the following research questions:

- What are the perceptions, beliefs, and knowledge of in-service high school science teachers about the Next Generation Science Standards (NGSS)?
- What types of professional development (if any) are teachers utilizing to help them understand and implement the NGSS?
- How (if at all) have teachers begun to shift their instructional practices to align with the vision of the NGSS? What areas need additional support?

- What factors are influencing teacher sense-making and implementation of the NGSS? What are some perceived barriers?

Research Design

With theories of teacher sensemaking supporting the methodology, this study used a mixed-methods design, which is a procedure for collecting, analyzing and “mixing” both quantitative and qualitative data during the research process to understand a problem more completely (Creswell, 2012; Tashakkori & Teddlie, 1998). This mixed-methods design allowed the researcher to capture both quantitative data and rich qualitative descriptions that would not have otherwise been available by using just one approach. Moreover, when used in combination, quantitative and qualitative methods complement each other and provide a more complete picture of the research problem (Creswell & Plano Clark, 2011; Greene et al., 1989; Tashakori & Teddlie, 2010).

Participants

Site selection. Two high school districts in Southern California, Hidden Valley Union High School District and Lincoln Union High School District (pseudonyms) were asked to participate in the study. These two districts were selected because they provided a representative sample of the student population in the region and the researcher already had an established relationship with each school. Prior to the study, an email was sent to each school district requesting their participation in the study (see Appendix C for introductory email communications).

Hidden Valley Union High School District is a suburban high school district comprised of three comprehensive high schools, a science and math academy, one continuation school, and one adult education school site. In 2016-2017, student enrollment was 9,578 and 69.9% of these students received free and reduced lunch (ed-data.org). The student population was 73.7% Hispanic, 19.0% White, 2.9%, Asian, 2.4% Black, and 2.1% Filipino (ed-data.org). In 2016-2017, Hidden Valley Union High School District was in their second year of transitioning to NGSS-aligned curriculum and instructional practices. The implementation process in Hidden Valley Union High School District was a collaborative process. Meaning, a representative group of teachers were brought together to develop content-specific pacing guides, curriculum, assessments, and laboratory activities. As such, all science teachers in the district were expected to use the prescribed curriculum. To support this process, the school district provided the following resources: two full-time science instructional coaches; teacher professional development opportunities; teacher release-time; and designated funding for equipment and supplies.

Lincoln Union High School District is a suburban high school district comprised of nine comprehensive high schools, two charter schools, one continuation high school, two alternative education school sites, and three special education schools. In 2016-2017, student enrollment was 21,709 and 58.4% of these students received free and reduced lunch (ed-data.org). The student population was 38.7% Hispanic, 42.6% White, 2.2% Asian, 6.8% Black, 6.9 % two or more races, 1.6% Filipino, 0.5% Pacific Islander, and 0.6 % Native American (ed-data.org). At the time of the study, the district science teacher on special assignment (TOSA) stated that Lincoln Union High School District was in their second year of transitioning to the NGSS. Similar to Hidden Valley, the implementation process in the Lincoln Union High School District was a collaborative process. However, in the Lincoln school district teachers were given the autonomy to develop their own curriculum. Also, even though the school district had hired a full-time science TOSA, other teacher resources and supports were school site specific.

Population selection. All comprehensive high school science teachers from the two districts were asked to participate in the study regardless of gender, race or ethnic background. For the purpose of the study, science teachers employed at charter or alternative education sites were not considered. These parameters were to limit the diversity of the respondents in order to capture more authentic teacher experiences and themes related to NGSS (Creswell, 2013). At the time of the study Lincoln Union High School District employed 69 science teachers who met the research design requirements, and Hidden Valley Union High School District employed 27 science teachers who met the requirements. An email was sent to all of the 96 science teachers in May 2017 requesting their participation in the first phase of the study (see Appendix D for the initial email to survey participants). To garner participants for the second phase, the last question of the survey asked the respondents if they were willing to be interviewed. The researcher via email (see Appendix E for initial email to interview participants) contacted this select group of individuals in June 2017 verifying their participation in the second phase of the study.

Data Collection

Data collection began in May 2017 and concluded in August 2017. The survey was administered over a one-month period of time, from May 2017 to June 2017. Interviews were conducted from June 2017 to August 2017.

After receiving approval from each school district, the researcher compiled a list of science teachers that met the parameters of the study. This list was generated with the help of the Director of Curriculum and Instruction from each district. Once this list had been compiled, a three-step survey administration procedure was followed for the first phase of the study (Creswell, 2012). In the first step, science teachers were sent an introductory email. This email included a personal introduction and background information about the study, delivery system of the survey, timeframe of when to expect the email with the survey link, and approximately how long the survey would take to complete (see Appendix D for initial email to survey participants). In the second step, teachers were sent another email invitation with an active survey link (see Appendix F for survey invitation). The third step of the survey administration involved three reminder emails with the survey link to elicit additional participation (see Appendices G and H for reminder correspondence). Reminder emails were only sent to teachers who had not yet completed or started the survey. Additionally, the first question of the survey included the consent form that informed participants they were voluntarily agreeing to participate in the study if they continued with the survey (see Appendix I for survey consent form).

The second phase of the study occurred between June 2017 and August 2017. The researcher contacted all ten participants who indicated on the survey they were willing to participate in the interview portion of the study (see Appendix E for initial email to interview participants). Eight individuals responded affirmatively and were contacted again by the researcher either by email or phone to make the necessary arrangements.

At the time of the interview, the researcher had each participant review and sign the consent form (see Appendix J for interview consent form). Participants were told they could withdraw or refuse to answer specific questions during the interview at any time without penalty. Participants were also given a copy of the consent form for their own records. Each interview was scheduled for 60 minutes and included 10 interview questions with room for clarifying questions as needed (see Appendix K for interview protocol and questions). Each session was recorded using a digital recorder on a personal password-protected electronic device. The researcher also took notes on a password-protected laptop during the interview. Since this study included audio recording, all interview participants were informed that the audio recording could be stopped at any time and that portions or the entire audiotape would be erased if requested. Safeguards were also put into place to minimize any risk to the participants. For example, pseudonyms were used for all teachers, and all email addresses and correspondence with participants were kept confidential and sent from a personal password-protected laptop.

After each interview all audio recordings were transcribed using a professional transcription service.

Instrument

The survey used in the first part of the study consisted of 100 items (see Appendix L for survey questions) that measured teacher knowledge, beliefs, instructional practices, school resources, and professional development participation. The survey was designed to take approximately 15-25 minutes to complete and was administered through a secured Qualtrics account. In several sections of the survey a Likert-type attitudinal scale was used to collect data, which brought some limitations (Creswell, 2012). Primarily, each statement offered a limited number of options for teachers to fully express their thoughts or opinions. This problem was addressed through open-ended survey questions and the use of qualitative data collection, which were both used to supplement the quantitative data.

The development of the survey was based on the research questions, sensemaking theoretical framework, and a review of existing literature. In Section A (items 2-10), teachers answered questions about biographical data such as age, gender, ethnicity, degree and teaching experience (Ajayi, 2016; Banilower et al., 2013). In Section B (items 11-23), teachers responded to statements about their knowledge of the NGSS (Ajayi, 2016; Banilower et al., 2013). In Sections C through G (items 24-60), teachers responded to statements related to their beliefs about the NGSS' vision of teaching and learning which included perceived effectiveness, confidence, motivation, and success (Haag & Megowan, 2015). In Section H (items 61-83), teachers answered questions about the implementation of NGSS-aligned practices in their classrooms (Hayes, Lee, DiStefano, O'Connor, & Seitz, 2016). In Sections I and J (items 84-97), teachers answered questions about school resources and implementation supports (Ajayi, 2016; Banilower et al., 2013; Lumpe et al., 2000).

The individual interview protocol with semi-structured questions was developed based on the research questions, sensemaking theoretical framework, review of existing literature, and survey responses (see Appendix K for the interview protocol and questions). Items from the interview included four major sections: (1) background questions; (2) NGSS knowledge; (3) NGSS preparedness and teacher change; and (4) implementation supports. Interviews were scheduled for 60 minutes and took place at a public location such as a coffee shop or public library.

Data Analysis

The quantitative data from the survey stored in the Qualtrics account was uploaded and analyzed using the SPSS + statistical software for descriptive and non-parametric statistical analysis. Prior to analysis, all quantitative data was cleaned, missing data was assessed, and the number of categories per instrument item were collapsed and recoded as needed (Creswell, 2012; Connolly, 2007). Descriptive analyses allowed for summarizing the overall trends in the data and areas of interest were highlighted through appropriate graphical representation. Non-parametric statistical analyses were also conducted for each instrument item in relation to the following demographic characteristics: years of teaching experience; teaching assignment; school district; and gender. Non-parametric techniques were chosen due to the small sample size of the study and because the data were measured on nominal and ordinal scales (Connolly, 2007; Pallant, 2013).

The survey instrument also contained six open-ended questions that gave respondents an opportunity to provide more information about their knowledge of the NGSS, their ability to implement these new practices within their own classroom, concerns related to classroom resources and professional development, and any other comments or concerns related to implementation of the NGSS. These questions were optional; consequently, not all respondents provided a response. When responses were initially reviewed, it was noted that teacher responses did not necessarily correlate with the open-ended question where the teacher wrote his or her response. As a result, all responses were organized into a single transcript, coded using descriptive and *in-vivo* coding, then categorized based on emerging themes.

The qualitative data, interview transcripts, and open-ended survey questions were uploaded and coded electronically using the CAQDAS software program HyperRESEARCH. In the first cycle of coding, the researcher conducted several iterations of eclectic coding for all text data (Saldana, 2016). Eclectic coding was used because it allowed the researcher to implement a combination of purposeful first coding methods (Saldana, 2016). As a result, during the first cycle of coding, a combination of initial, descriptive, emotion, and value coding were used to summarize segments of text (Miles, Huberman, Saldana, 2014; Saldana, 2016). In the second cycle of coding, a combination of pattern and focus coding was then used to condense these summaries into smaller units to create categories, and the interrelationships of these categories were then used to identify the main themes and subthemes of the study (Miles, et al., 2014; Saldana, 2016).

An integration of the quantitative and qualitative data collected took place as the final step in the analysis. All patterns and findings from both phases of the study were connected and compared via the lens of the current literature in order to examine the relationship between the quantitative and qualitative findings (Creswell & Plano Clark, 2011). The goals of integrating the data and pursuing a mixed-methods approach were to provide the most in-depth understanding of the research questions and to add value and strength to the findings (Creswell & Plano Clark, 2011).

Limitations

Generalizability. This investigation was limited in scope and context because it only examined the experiences of a small sample of participants gathered from two school districts. As a result, responses and experiences recorded will be unique to those teachers and their corresponding schools. Nonetheless, even though each participant's experience was unique, there were commonalities across teacher experiences and school districts that could be useful for policy makers, researchers, and educational leaders.

Positionality. Since I am a school site administrator in the Hidden Valley Union High School District, positionality was a potential limitation. As a result, science teachers within my district who were solicited to participate may have experienced the following emotions: fear, anxiety, distrust, and stress. Additionally, individuals who did participate in the study might have felt reluctance to voice their concerns or opinions, or their responses might have reflected what they thought I wanted to hear. In an attempt to minimize the role of my position in the district I incorporated the following parameters: I did not solicit participation at my own school site, participants were contacted using my personal university email account, the study was not discussed in the work setting, all correspondence iterated how confidentiality was being maintained, interviews were conducted off-site to instill a sense of neutrality, and during the interviews all conversation was related to the study.

Chapter Summary

A two phase mixed-methods research design was chosen to effectively answer the research questions for this study. The research methodology was designed through a review of the literature on the NGSS, curriculum reform and policy, teacher responses to the implementation process, and the sensemaking theoretical framework. The purpose of this study was to determine how school leaders can better support teachers during the NGSS implementation process by examining: (1) how teachers are making sense of the Next Generation Science Standards (NGSS); (2) teacher responses, or instructional changes, that are already being implemented and areas that may need additional support; (3) the types of professional development and support systems teachers are utilizing to help them make sense and respond to the NGSS; and (4) the implementation challenges and/or barriers teachers are facing during the implementation process. By implementing both qualitative and quantitative data collection, a deeper and richer understanding of teacher experiences in these areas was provided.

Chapter 4: Analysis

In this exploratory, mixed-methods study, both quantitative and qualitative data were collected and analyzed in a two-step process as a means to better understand how teachers are constructing students' learning experiences in congruence with a new reform policy and/or how teachers themselves learn new ways of teaching. The first step of the research design utilized a survey that included both closed and open-ended questions to capture qualitative and quantitative data about teacher knowledge, beliefs, instructional practices, professional development opportunities, and the school environment. The second step of the research design entailed semi-structured interviews focused on teacher knowledge, experiences, professional development, classroom practices, and the school environment.

Demographic Profile of the Participants

The online survey was sent electronically to 97 high school science teachers employed within the Hidden Valley Union High School District and the Lincoln Union High School District (pseudonyms) located in Southern California. Out of the 97 requests for participation, surveys were obtained from 42 respondents, but only 37 were fully completed and used for the study (see Appendix M for full demographical data of the participants). The gender makeup of the participants included 13 males and 23 females. Twenty-four of the teachers were employed in the Lincoln Union High School District and thirteen were employed in the Hidden Valley Union High School District. One hundred percent (37 of 37) of the survey respondents were certified to teach science and 86% (32 of 37) obtained their teaching credential through a post-baccalaureate program. Fourteen percent (5 of 37) of the teachers only had a bachelor's degree while 86% (32 of 37) held master's degrees. Seventy-three percent (27 of 37) of the teachers were over the age of 35 and 73% (27 of 37) had been teaching more than 10 years. Biology was the primary teaching assignment for 59% (22 of 37) of the respondents.

Out of the 37 individuals who completed the survey, eight of those individuals also agreed to participate in the interview portion of the study (Table 2). As a whole, these eight individuals reflected the larger study population.

Table 2*:* Demographical Data of Interview Participants

Teacher Name*	Gender	School District *	Teaching Experience	Current Teaching Assignment	Self-Reported Classroom Implementation of the NGSS
Brian	Male	Lincoln UHSD	24	Biology	High
Gabe	Male	Lincoln UHSD	16	Chemistry & Biology	Medium
Katherine	Female	Lincoln UHSD	18	Biology & Chemistry	High
Stephanie	Female	Lincoln UHSD	16	Chemistry & Physics	Medium
Amy	Female	Hidden Valley UHSD	13	Biology	Low
Bianca	Female	Hidden Valley UHSD	4	Physics	High
Brianna	Female	Hidden Valley UHSD	20	Earth Science, Oceanography, & Sheltered Earth Science	Low
Tanya	Female	Hidden Valley UHSD	6	Basic Biology & Basic Earth Science***	Low

**Pseudonyms*
*** Sheltered refers to a class designated for English Language Learners*
**** Basic refers to a course designated for students in the special education program*

Data Analysis

Analysis of both quantitative and qualitative data was organized and aligned with the research questions. Quantitative data from the survey were analyzed first in order to determine key trends or patterns. Open-ended questions from the qualitative data (survey and interviews) were analyzed qualitatively, by identifying emergent themes within the participants' responses. Selected quotes relevant to the research from the eight teacher interviews were also provided.

Items on the survey were broken down into five major sections. The sections included: (1) background information (demographics); (2) NGSS Knowledge; (3) NGSS beliefs; (4) NGSS instructional practices; and (5) NGSS Implementation resources and supports. Items from the interview were also broken down into five major sections: (1) background questions; (2) NGSS knowledge; (3) NGSS preparedness and teacher change; (4) implementation resources & supports; and (5) teacher beliefs.

Research question one. What are the perceptions, beliefs, and knowledge of in-service high school science teachers about the Next Generation Science Standards (NGSS)? When implementing new reform efforts, such as the NGSS, it is important to take a closer look at factors that may influence teacher responses to the new policy. For instance, researchers have well documented the influence of teacher beliefs about instruction, students, policy, and school environment on teacher instructional practices (Gess-Newsome, 1999; Hopkins & Spillane, 2015; Johnson & Bolshakova, 2015; Lumpe et al., 1998; Pajares, 1992). It has also been well established that teacher actions will differ based on internal factors such as teacher motivation, teacher self-efficacy and teacher knowledge (Keys & Bryan, 2001). Therefore, in an effort to better understand how teachers make sense of and enact new reform policies, the first research question in this study sought to examine teacher perceptions, knowledge, and beliefs regarding the NGSS. Teacher perceptions, beliefs, and knowledge were gathered from the following survey and interview sections: (a) NGSS knowledge (survey and interview); (b) NGSS beliefs (survey and interview); and (c) NGSS preparedness and teacher change (interview). Four primary findings associated with the first research question were identified and are discussed in more detail below.

Finding one. Teachers reported having some knowledge and understanding of the key components of the NGSS but were less confident about their skills and knowledge relative to engineering practices. As teacher knowledge is generally related to practice (Abell, 2007), a fundamental assumption of this study was based on the premise that teachers would have some understanding of the NGSS in order to implement new instructional practices in their classroom. This assumption was based on research showing that knowledge, in general, is essential for the enactment of reform-based teaching practices (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). To measure teacher knowledge and understanding of the NGSS, survey items asked teachers to "rate their understanding of the following changes to science education envisioned in the Framework for K-12 science education and carried forth in the NGSS" (adapted from Ajayi, 2016; Banilower et al., 2013).

Survey item responses indicated that 100% (37of 37) of the teachers had some knowledge of the key components of the NGSS. In particular, as shown in Figure 1, teachers were the most familiar with the areas of Three-Dimensional Learning, Disciplinary Core Ideas, and Crosscutting Concepts.

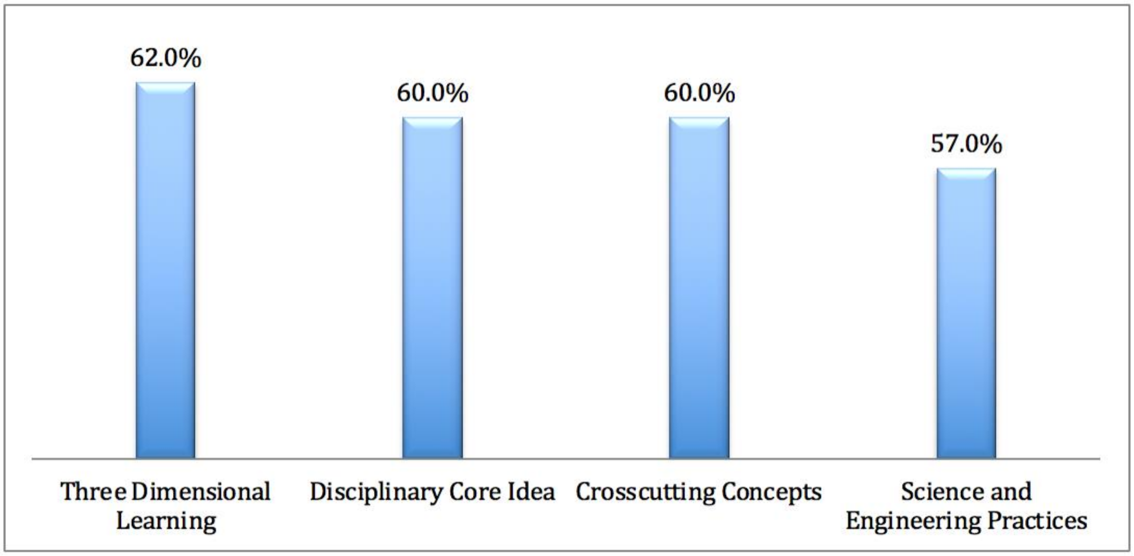

Figure 1: Teacher Knowledge: NGSS. “Highly Familiar” teacher responses to survey items related to teacher knowledge about the NGSS.

Additionally, when teachers were asked to describe their knowledge of the NGSS during the interviews, they often used the following phrases in their responses: “phenomena,” “mental models,” “collecting data,” “comparing data,” “analyzing data,” “graphs,” “summarizing findings,” “questioning,” “models,” “launch,” “representations,” “claim evidence in reasoning,” “white boards,” and “group work.” For example, Bianca included several of these phrases related to how she structured her lessons:

> I always start off with a launch or a phenomenon where I show them something cool, like a ball dropping, or a pendulum swinging, or a car moving. Then we record our observations and look at how these two measures related to each other. Then I give student 20 minutes or more to plan and then carry out their own investigations so they can determine the relationship between those two things. I tell them what I expect the product to be. Sometimes it’s a graph, sometimes it’s a model, or an equation. Then we debrief using whiteboards. I then have them summarize their learning.

Katherine also used several of these phrases when she described a lesson in her class:

> A typical start to a lesson for me would be introducing them to a phenomenon. Then I give them the explanation, whether that’s direct instruction or they are working in groups. Then they come back to their mental model. They look at their

> first model and the guiding question at the top, and then they revise their model now that they have more information.

Gabe described how he rearranged his classroom to promote more group work and the use of white boards:

> So now my chairs are arranged in groups of four and they are arranged in a way that everybody kind of looks at each other…they have no choice. This way it is easier to do more pair share or group work…I can also go around and ask them to pick a spokesperson for their group. We also do a lot more white-boarding…its easier with them in groups of four.

Brian described how he used phenomena in his lessons:

> So I put together a bunch of macromolecules, ballistic method drawings, illustrations, etc. I then put them on a sheet in random order and say to the students, "ok we have these items, and if you were going to organize them how would you do it?"

Combined, these responses indicated that teachers were beginning to develop some common language around the NGSS.

However, further data analysis suggested that teachers were not as familiar in the area of engineering compared to other concepts emphasized in the NGSS. For example, when teachers were asked to rate their knowledge and understanding of Science & Engineering Practices, 57.0% (21 of 37) of the teachers responded they were highly familiar with these practices (Figure 1). Yet, only 35.0% (13 of 37) of the teachers reported being familiar with Engineering Design. Statistical analysis also indicated differences between teacher knowledge and their primary teaching subject related to the survey element Engineering Design (p = 0.02, Kruskal Wallis H = 11.79, df=4;). As shown in Figure 2, physics, physiology, and chemistry teacher median scores indicated more familiarity related to the concept Engineering Design compared to biology and earth science teacher median scores.

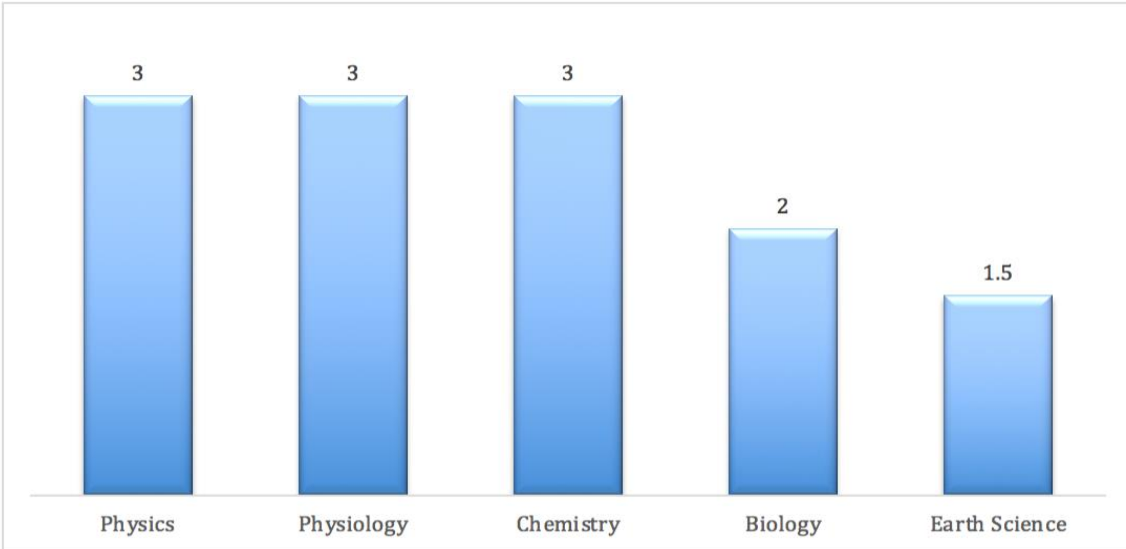

Figure 2: Engineering: Statistical Analysis. Teacher median response scores by content area related to teacher knowledge about engineering design.

Teachers were also asked to respond to their level of confidence in implementing NGSS-related tasks in their classroom (adapted from Haag & Megowan, 2015). As seen in Figure 3, 100% (37 of 37) of the teachers agreed they could typically answer student science questions, but only 57.0% (21 of 37) agreed they could answer student questions related to engineering. Likewise, 92.0% (34 of 37) of the teachers agreed they could design and deliver science activities, but only 43.0% (16 of 37) agreed they could design and deliver engineering skills. These results suggested that teachers were less confident in their abilities to implement engineering-related tasks in their classroom compared to implementing traditional science activities.

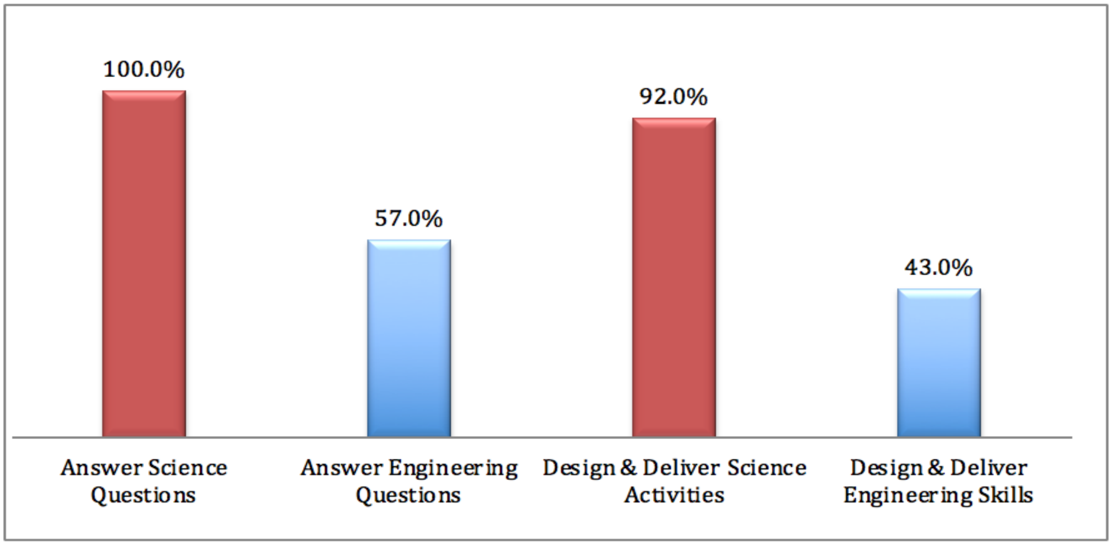

Figure 3: Teacher Confidence: Engineering. "Agree" teacher responses related to teacher confidence levels in implementing engineering tasks in the classroom.

Statistical analysis also indicated a difference in teacher confidence levels related to the survey element "Answer engineering questions" between the two school districts ($p < 0.007$, Mann-Whitney $U = 80.00$, $Z = 2.71$). Hidden Valley Union High School District teachers were more confident in their ability to answer students' engineering questions than teachers from the Lincoln Union High School District. The strength of this relationship between school district and confidence level was medium ($r = 0.45$).

Additionally, teachers were asked to rate how motivated they were to implement NGSS-related tasks in their classrooms and their anticipation of success (adapted from Haag & Megowan, 2015). As illustrated in Figure 4, survey item responses indicated that over 76.0% (28 of 37) of the teachers were highly motivated to implement various engineering practices in their classroom. However, anticipation of success varied from 51.0% (19 of 37) to 73.0% (27 of 37) depending on the task. This suggests that while teachers were motivated to implement and perform engineering tasks, they did not anticipate successful outcomes.

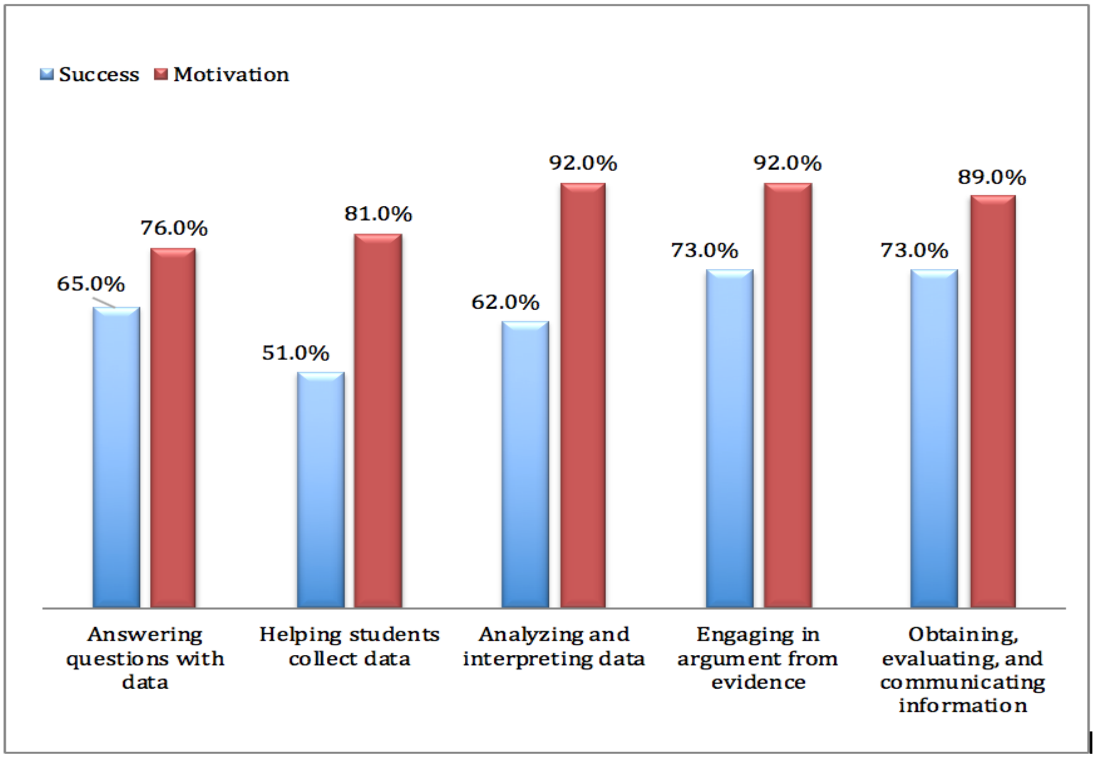

Figure 4: Teacher Motivation: Engineering. "Highly Motivated" and "Above Average Success" teacher responses relative to teacher motivation and anticipation of success in implementing engineering tasks in the classroom.

In total, although teachers felt confident and knowledgeable implementing new practices associated with the NGSS, teachers consistently reported feeling less confident about their skills and knowledge relative to engineering practices. For instance, while most of the teachers agreed they could typically answer student science questions and design science activities, less than half of the respondents felt they could answer student questions and design activities related to engineering practices. Likewise, they did not anticipate great success in implementing engineering-related practices in their classrooms, despite high levels of motivation.

Statistical analysis also brought forward two unexpected outcomes regarding teacher knowledge and science and engineering practice. First, physics, physiology, and chemistry teacher median scores indicated more familiarity related to the concept Engineering Design, compared to biology and earth science teacher median scores. Second, Hidden Valley Union

High School District survey responses indicated teachers from this district were more confident in their ability to answer students' engineering questions than teachers from the Lincoln Union High School District. These findings are interesting and suggest the need for additional research focused on the relationship between engineering practices and school contextual factors.

Finding two: Teachers had differing levels of knowledge and understanding on how to use performance expectations to assess student learning. Traditionally in science education, students are tested on what they know and understand through some sort of written quizzes or exams. Now, student learning should be assessed through the use of NGSS performance expectations (PEs), which describe what students should know and be able to do by the end of each grade level or course (Bybee, 2013). Additionally, since PEs link disciplinary knowledge, a science practice, and a crosscutting concept, assessments must also encompass all three strands (Cooper, 2013). As a result, a teacher will no longer be able to assess student learning of a standard solely by recall of factual knowledge (Cooper, 2013). In turn, this will require teachers to assess student learning based on mastery of science skills and concepts over a period of time, an entirely new approach in science education (National Research Council, 2015).

While survey and interview data indicated teachers were familiar with the NGSS performance expectations, the data also indicated that many were still unclear about how to actually assess student learning using this new methodology. For example, as shown in Figure 5, survey item responses indicated that 54.0% (20 of 37) of the teachers were highly familiar with the performance expectations and 51.0% (19 of 37) were highly familiar with how the performance expectations related to curriculum development. However, only 41.0% (15 of 37) of the teachers were highly familiar with how they related to student assessments.

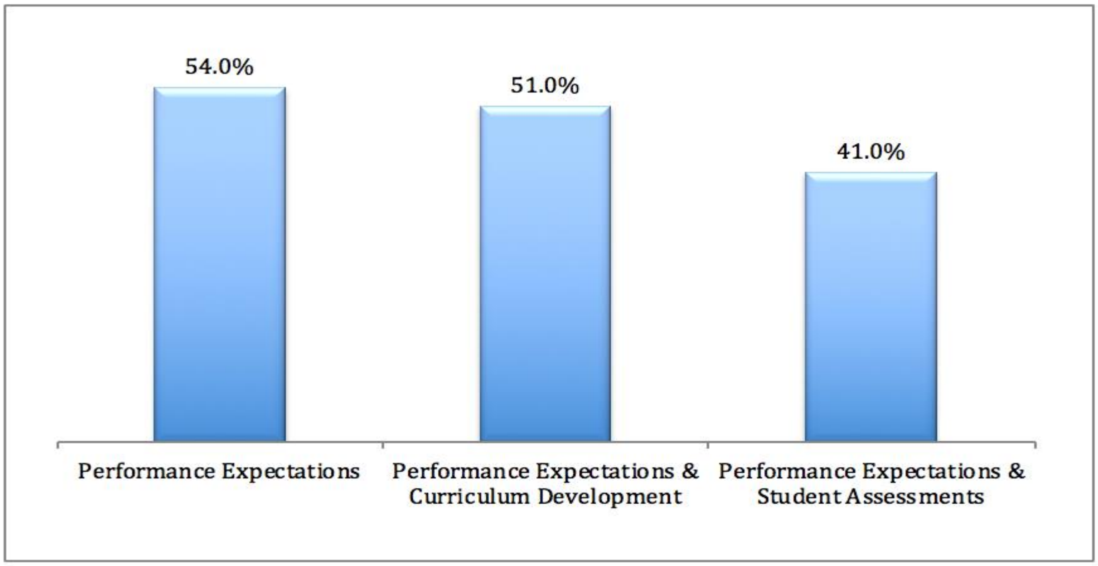

Figure 5: Teacher Knowledge: Performance Expectations. "Highly Familiar" teacher responses to survey items related to teacher knowledge about NGSS Performance Expectations.

Also, during the interview process when teachers were describing areas in which they needed additional support, several of the teachers mentioned performance expectations. For example, Amy and Tanya said they did not understand how their classroom assessments needed change or what to do when their students were not progressing. Amy commented:

> How do our assessments need to be different? I've also tried, in terms of the assessments, to do some open-ended instead of just multiple-choice. What I found in the past is that on tests, if it's not multiple-choice or matching or true false, when I have those open-ended type questions, a lot of students will just leave them blank. What do I do when the students just leave it blank? That's a big concern for me.

Tanya had similar thoughts:

> So what does that look like? I still haven't got an answer to that piece of it. What if I have a kid that, by the end of the school year, won't do it, can't do it, was absent every time I tried to assess this, what does that look like? Did they pass the class by meeting eight out of the ten performance expectations? That's what I'm confused with. Do we fail them and make them repeat the class so they can show mastery?

Tanya was also concerned about grading practices in this new system:

> What stresses me out the most is the grading piece of it. We are point heavy right now. You know what I mean? All the little ten point worksheets. Right now kids can do all of those and then fail every test, but they can still pass the class with a D. Now, if we flip that and their grade is based on performance expectations, what is that going to look like? Are more kids going to fail? Then what do we do?

On the other hand, while Bianca, Gabe, and Stephanie appeared to be more comfortable with the new assessment system, their statements reflected varying degrees of understanding and implementation. For example, Bianca stated she used the PEs to backwards plan:

> I am writing my tests directly from those learning objectives (performance expectations) so I am backwards planning. I'm not an expert at it yet, but I think that's the way to go as far as forming assessments. I also offer multiple opportunities to demonstrate mastery. So something that I let students know is that they're just expected to try and do their best. I do not expect everyone to get it the first time. And if it takes them trying the quiz, or the test, or an assignment, a problem set, 2, 3, 4 times to really get it right, let's do that. Let's take advantage of that. I also don't deduct points for late work. I don't deduct points. I know students are more often motivated by grades, so I'll make a point to tell them that their grade won't be affected negatively, even if it takes them a week longer to master the skill or concept than someone else.

Gabe stated he assessed student knowledge by monitoring what the student has learned over time. However, the lack of detail in his statement suggested he had not tackled this issue yet in his classroom:

> I know in the back of my head, he doesn't have to be good at it right now, because I'm gonna ask this kid next month, the same questions again, and I'm gonna ask him in May the same, and hopefully he will be good at it by the time June comes rolling around. From my perspective, that’s what's kind of freeing for me is that my kid doesn't have to have things characterized, he just needs to be better at the end of the school year than in the beginning.

Stephanie also stated she had started to change her classroom assessments by incorporating more open-ended questions, but did not talk about the role of PEs:

> We've already added, especially to the chemistry, we've changed our tests to be, "Do you agree or disagree and why?" It doesn't put a lot of math in it, but it emphasizes why they are choosing to agree or disagree and there's no one right answer. They can tell me if they disagree, they can tell me why, and if they're halfway right, I'll give them a point. It's not an all or nothing, and so that has been,

> I think, meaningful for students, and then they go over and we do the corrections, and so they get to go back and relook at their work.

In conclusion, both survey and interview responses indicated that teachers were concerned about how to effectively assess students using the NGSS Performance Expectations. Consequently, many teachers still need time, support, and assessment tools to create instructional environments where their students have adequate opportunities to learn what is now expected of them (National Research Council, 2012).

Finding three. Despite feeling prepared to implement the NGSS, teacher emotions related to ability and professional identity were being negatively impacted. Teacher emotions are intricately tied to teacher beliefs about educational change (Hargreaves, 2004). A teacher's emotional response towards change is defined as the way an individual perceives, interprets, and evaluates one's relationship with the changing environment (Zembylas, 2003). Yet teachers respond to school reforms in a variety of ways. Some teachers are happy to support and sustain reform efforts, whereas others feel fear, frustration, or loss and resist such efforts (Datnow & Castellano, 2000; Hargreaves, 2005; Lasky, 2005; Van Veen & Sleegers, 2006; Van Veen et al., 2005; Zembylas & Barker, 2007). Interview data validated the view that emotions play a role in teachers' experiences of change, especially in the areas of teacher preparedness, ability, and professional identity.

Interview data indicated that teachers felt prepared and confident in implementing the NGSS practices in their classrooms. Bianca stated she felt "prepared" because as a new teacher she only knew how to teach using the practices consistent with the NGSS. Brianna said she felt prepared because she "knew how to read the standards, the crosscutting concepts, and the STEM things." Gabe felt he was "more versed in the NGSS than most people, most science teachers" and Katherine said she started to feel “pretty well-prepared last year, but she knows there is always room for improvement.” Likewise, Brian commented on his level of preparedness:

> I personally feel at this point right now; I feel like I'd give myself an eight out of 10. Like I know how this stuff works and I know where we're going and I have a foundation to work form. Not that last year was awesome. It was good, it was a great start, I think. But it's not done, it will never be done but there are always things that I can do better.

However, despite feeling prepared, some teachers were still concerned about their ability to meet the new expectations. Amy said it was going to be “hard with so many unknowns” and it was “kind of scary.” Other teachers expressed mixed emotions about the NGSS. Brianna described the formation of the NGSS as “someone grasping at straws” and “like scattershot.” In the same way, Stephanie reflected that while the NGSS was “good stuff” she still felt like “we’re reinventing the wheel where we do not necessarily have to.” Tanya indicated that the NGSS were going to be “too time consuming.”

For some teachers, the implementation process was threatening their professional identity. For instance, Amy self-identified as a “traditional teacher” and with the transition to the NGSS she was questioning her own skills as a teacher:

> I was always taught where at the beginning of the unit you're going to take notes, you're going to do some worksheets where you're practicing the information, you do some sort of lab. Then you have to analyze and graph data, and answer some conclusion questions, but it's not necessarily you asking questions and you designing the labs. So doing things that are NGSS is going to be hard. It's going to be hard as a teacher because it's easier to just give information, and give them a lab, and give them a multiple-choice test. I think that I’m going to need constant reminders and refreshers until it becomes habit.

Amy also felt it would be hard to change her practice based on her prior experiences with science education. As she effectively stated, “when we teach, I think a lot of the times we teach the way we were taught.”

Brianna viewed herself as an “earth science teacher,” but felt with the transition to the NGSS and realignment of the science courses in her district, this identity was being threatened. As a result, Brianna during the interview she expressed fear and frustration about her role as a science teacher in the upcoming years:

> Yeah, we need a decision made and then to either move forward or to tell me where I'm supposed to go. If I'm supposed to teach Biology then they need to bring me up to speed on that or give me the opportunity to get up to speed on that. If I'm teaching Math I need to go through training for that. And I don't want to do it two weeks before school starts, which is kind of how things work...I know it sounds really negative, but I am tired of nobody making a decision.

When asked what she thought she might be teaching in the future Brianna discussed her other certifications, but it was evident she saw primarily as an “earth science” teacher:

> I'll have to either pick up biology classes or math classes. Those are my other two areas of certification but I don’t want to have to start over…you know what I mean? I was thinking about taking the test to teach chemistry, but I'm not sure I want to do that because I don't know if I want to teach Chemistry. I don't have the love for it. You know? I could do that, but I'm not sure I want to do that. I like Chemistry well enough, I just don't know if I want to teach it.

In the same way, Stephanie commented about the loss of status when she went back to teaching after taking a break to raise her children:

> The difference was before, when I taught in [name of former school district] I was a teacher mentor, a department chair, I served on various committees within the district. I had lots of opportunities to attend conferences, work with other people, and share my ideas. Now, not so much.

Gabe saw himself as an NGSS expert, but with little to no status within his school or school district:

> I'm not even on anybody's radar so I'm just kind of a guy who knows stuff but nobody wants to listen to me. I'm doing stuff on my own, which is depressing but, whatever. That is the only reason why I would go back and get a doctorate degree so that I can lead conversations and people would take me seriously.

Bianca consistently referred to herself as a "new teacher" during the course of the interview. Moreover, she felt as a new teacher in her department she did not have the skills needed to talk to her colleagues about instruction:

> In my first year I was the only new teacher in my department. It was hard for me to figure out what my place was in the department. I did not want to come off as arrogant or a know-it-all, but I also wanted to contribute and did not know how. I don't think the credential program properly prepared me for working with teachers that had absolutely no exposure. So it's taken me a couple years to kind of figure out how to talk about NGSS in a way that is accessible to others, because all I know is NGSS.

Brian also appeared uncertain about his role in his school and department. Prior to transferring to his current school, Brian had already been teaching for several years, and described himself as an AVID teacher trainer and water polo coach. However, in his department he described himself as a "new teacher" with little "seniority":

> I have the least seniority and we're going through a transition right now and I'm playing this weird role. I thought I was going to be teaching chemistry this year but that didn't work out because I think they want me to stay with biology.

In total, teacher narratives revealed that emotions related to level of preparedness, ability, and identities were being impacted by the implementation of the NGSS. While some teachers "felt prepared" and were experiencing positive feelings, others were experiencing conflicting and even negative feelings such as frustration and resentment. In turn, these conflicting and negative emotions appeared to be influencing teacher identity, which could also impact the implementation of a new policy (Van Veen et al., 2005).

Finding four. Teachers expressed mixed beliefs and attitudes towards the NGSS goal of "all standards, all students." The NGSS idea of "all standards, all students" was based on the premise that all students can learn science skills and concepts despite any differences in opportunities to learn if they are provided with rich and meaningful learning opportunities through the use of effective teaching strategies (National Research Council, 2015). As such, the NGSS focuses on instructional strategies that encompass a range of techniques that build on students' interests and backgrounds so as to engage students more meaningfully and support them in sustained learning. Moreover, an important element of many of these instructional approaches is recognizing the assets that students from diverse backgrounds bring to the science classroom and building on them (NGSS Lead States, 2013, Appendix D).

However, teacher beliefs can play an important role in many aspects of teaching. In education, teachers' beliefs can be described as their convictions, philosophy, or opinions about teaching and learning (Coburn, 2005a, 2005b; Fullan, 2016; Johnson, 2007b). Consequently, teacher beliefs influence their perceptions and judgments, which, in turn, affect their actions in the classroom (Pajares, 1992). Specific to science education, Milner et al. (2012) argued that teacher beliefs about student learning substantially affect planning, teaching, and assessment. Thus, having a better understanding about the relationship between teacher beliefs and student learning in the context of science education reform is central to improving science education instruction.

Therefore, to gain a better understanding of teacher beliefs about student achievement relative to the NGSS, survey items asked teachers to "indicate the degree to which they agreed or disagreed" with various statements related to student achievement, teacher effectiveness, and effective teaching practices (adapted from Haag & Megowan, 2015). As shown in Figure 6, survey item responses indicated that 100.0% (37 of 37) of the teachers were continuously trying to find better ways to teach science and 76.0% (28 of 37) of the teachers felt the inadequacy of a student's science background could be overcome with good teaching (Figure 6). Additionally, 57.0% (21 of 37) of the teachers agreed if a low-achieving student made progress in science it was often due to extra attention from the teacher and 51.0% (19 of 37) of the teachers agreed they were responsible for student achievement in science. Overall, these results suggested that teachers agreed there was some correlation between student science achievement and the teacher.

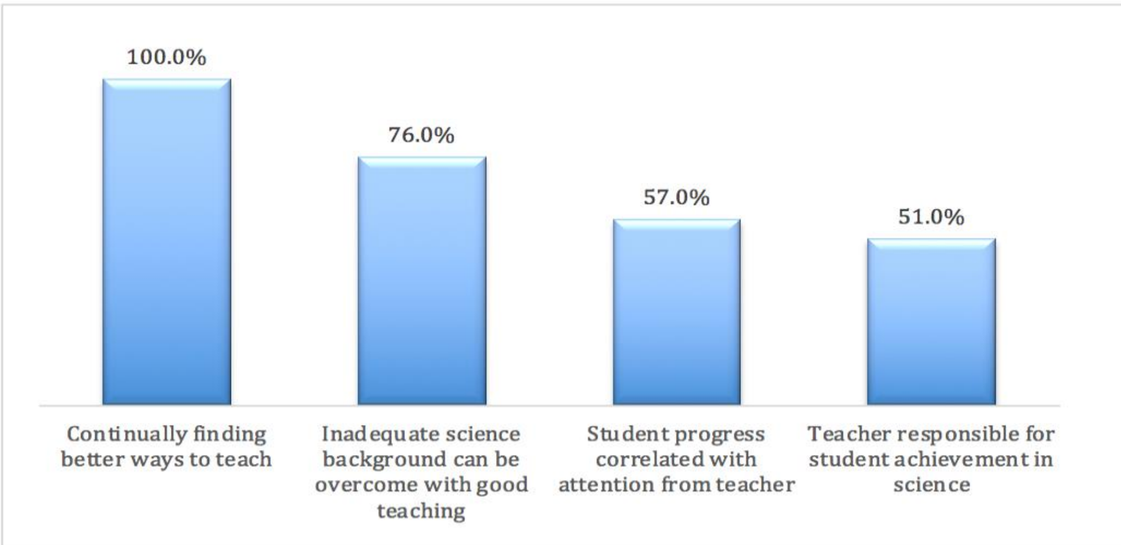

Figure 6: Teacher Beliefs: Student Achievement. "Agree" teacher responses to survey responses related to teacher beliefs about student achievement.

On the other hand, teachers were divided about the association between student achievement and effective teaching practices. For instance, as illustrated in Figure 7, item responses implied 41.0% (15 of 37) of the teachers agreed student achievement could be correlated to effective teaching practices, whereas 43.0% (16 of 37) of the teachers agreed there was not an association. Yet, item responses indicated that only 14% (5 of 37) of the teachers felt student underachievement in science was a result of ineffective teaching practices, and 49.0% (18 of 37) believed if a student improved in science it was due to more effective teaching practices. This last point appeared to suggest that teachers believed other factors, not just teaching practices, contributed to student underachievement, an assumption that was supported by findings in the open-ended survey questions.

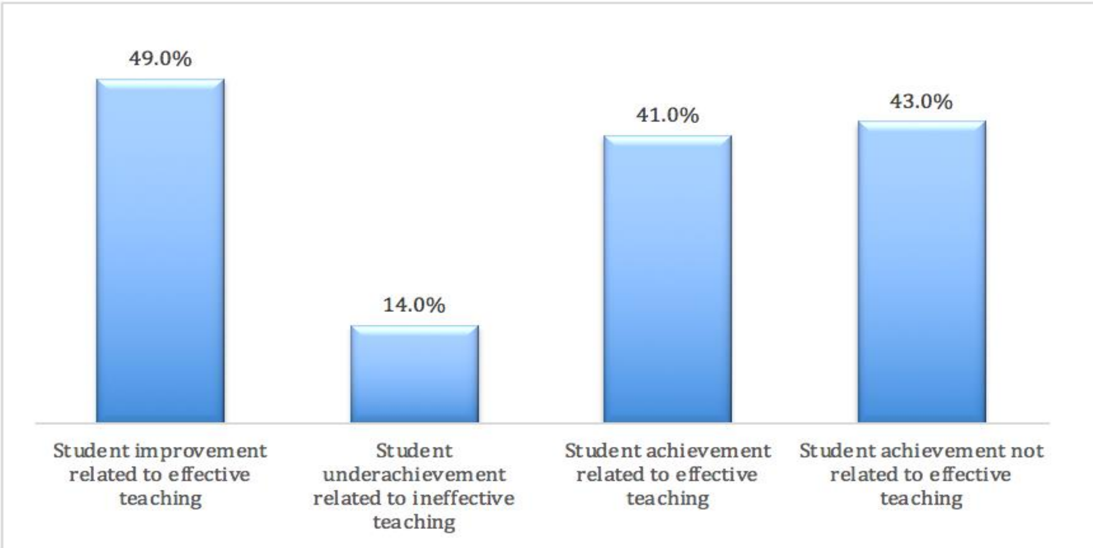

Figure 7: Teacher Beliefs: Effective Teaching. "Agree" teacher responses to survey items related to teacher beliefs about the relationship between effective teaching practices and student achievement.

Responses in the open-ended questions indicated that teachers believed the NGSS practices could not overcome differences in achievement due to differences in opportunities and inequities within the school system. For example, while several of the teachers stated the NGSS were a step in the right direction because they would require students to think and problem solve, they felt the students would still not be able to access the curriculum. As one teacher stated, "I worry about the continued decline of students' ability to persevere through challenging curriculum because it will require higher levels of thinking and student engagement." Teachers also expressed concern about low student motivation and student reluctance to engage with the lesson. One teacher felt that "students prefer and ask for worksheets, textbook work, or other boring work instead of an activity that requires thought, interaction, or energy." Some teachers also identified student background, absences, and truancy rates as areas of concern related to student achievement in science.

Combined, these results suggested: (1) teachers recognized there was a relationship between teachers and student achievement; (2) teachers did not identify a strong association between student achievement and effective teaching practices; and (3) teachers were not optimistic the NGSS and related practices could overcome lack of student access and other educational barriers.

To further elucidate these points, during the interview portion of the study teachers were asked to explain their thoughts about the impact of the NGSS-aligned instructional practices on student achievement. However, interview data was similarly inconsistent on whether or not effective teaching could overcome differences in achievement due to differences in opportunities and inequities within the school system. For example, during their personal interviews, Brianna, Stephanie, Amy, and Tanya did not appear to believe that the teacher or effective teaching practices could influence student science achievement. Brianna commented:

> At our school, it's roughly 82% free and reduced lunch, majority Hispanic, many undocumented, many first generation high school graduates. Some of my students' parents have a third-grade education. I teach sheltered classes. Those kids come from various countries. Guatemala, Iran, of course Mexico, and the barriers are there.

Stephanie's statements also reflected her belief that the transient nature of her student population hindered their ability to be successful in science due to their learning gaps:

> We're over half Hispanic. I want to say like 66% or something like that. I think in the 20% range for African American. In [name of an affluent school district nearby] you see this progression of learning. I see none of that at [her school] in terms of students coming in with the same skills. It is so transient. If we have 100 kids coming in for freshmen, we're only going to have 25 of those as seniors. How can you be consistent and spiraling the curriculum, if you can't hold on to those kids? It's ridiculous.

She also believed a student's ability in science was connected to their math skills:

> I don't feel like any of my students are truly ready for the engineering right now, this might change with [name of professional curriculum] but I'm not sure

> because it’s so dependent on math. It’s not just thinking. It’s math, and you’d have to be comfortable with that, and that has to start pretty young to match the science, otherwise you’re always catching up. But if they don’t have the math skills, they’re not getting into a STEM-related field.

Amy felt students overall were going to struggle with the new classroom expectations because students were not motivated:

> Well, I think it is going to be hard to get them to create the experiment themselves. Some groups that just aren't going to do it. I think that a lot of times students, their natural reaction if they don't understand something, is to just kind of shut down. I think we are going to need to build in some remedial support for these students.

Tanya also commented on lack of student motivation:

> Well, I think our kids aren't used to it right now. The kids aren't used to that kind of work in science classes. They're used to the sit and get, and repeat on a...spit back out on a test. That will be a struggle. I think there will be a lot of pushback from students. Also how are we supposed to get students to participate if they are not motivated? I’m excited about the NGSS, but I’m also very nervous about our students that aren’t very motivated.

Yet other teachers, such as Brian, Bianca, Katherine, and Gabe felt it was the responsibility of the teacher to ensure all students could access and understand the skills and concepts outlined in the NGSS. Brian discussed his school demographics, which had a large population of ELLs, and how he thought all of his students should be able to access and understand the skills and concepts outlined in the NGSS:

> We are a Title I school. I know that the student population that we have we are about 50% were free and reduced lunch so it's a relatively low socioeconomic but we have this contrast with kind of high-end students as well. [Name of city] has the second largest Muslim immigrant population in the country so many of our students have some connection with the Middle East, we have a large Hispanic population as well. But, I don't think there should be any difference in their access to [NGSS practices].

Bianca also described how when she first started teaching, her class was predominantly made up of white males, but due to her belief that anyone could access physics, she now had more ELL students taking physics:

> I can remember back to my first class being majority white male. As I've been teaching there longer, there has been a pretty even split between White, Latino, and Asian. I have also seen a definite increase in English language learners. I think I am seeing more students because my goal is to break down this misconception, this assumption, that physics is only for the elite, or that it requires a lot of math.

Katherine acknowledged the educational challenges related to student background, but described how she accessed additional support systems within her school to help her ensure all of her students were successful in science:

> Our population is just under 50% English language learners. We have students from Iran, Iraq, Syria, and Turkey. We also have a high Spanish speaking population, then African American, white, and other students. But, predominately our students are English language learners. We have what's called a task force at our school, an ELL task force. So there's a lot of support for our ELLs and that task force delivers PD all year for us. Whenever I have issues with a text I am using, I go to one of them and they help me with literacy strategies so that they (ELLs) can get what an American student gets out it.

Katherine also indicated that she found her ELL's to be more motivated:

> Also it is just different teaching sheltered. They tend to be more motivated and value their education than students I've had in the past. Of course, you always have a few that aren't, but in general, my kids are always working and wanting to learn and wanting to know. It's pretty refreshing.

Gabe commented on his school demographics as well and how it had impacted his classroom and his role as a teacher:

> I think we're like 85%, free and reduced. It's a lot of Spanish, like Mexicans, a lot of Middle Eastern. More and more refugees are also coming in. So, very high ELL population and low SES so, a lot of kids with single parents or grandma and grandpa raise them 'cause the parent can't, that kind of thing. I think it's really up to me as a teacher to act like their coach. As an athlete, you're only as good as your coach right? So I feel like the same way in the science classroom it's like, these kids are only as good as what I put in front of them and I give them the opportunity to do.

Overall, these mixed findings emphasize that teachers in this study believed their instructional practices did not necessarily affect all students equally.

Research question two. What types of professional development are teachers utilizing to help them understand and implement the NGSS? The second research question in this study sought to examine the types of professional development teachers were accessing to increase their own knowledge of the NGSS. The types of professional development and teacher perceptions of the professional development sessions were gathered from the following survey and interview section: NGSS Implementation resources & supports. One primary finding associated with the first research question was identified and is discussed in more detail below.

In education, the term "professional development" may be used in reference to a wide variety of specialized training, formal education, or advanced professional learning intended to help educators improve their professional knowledge, competence, skill, and effectiveness (Loucks-Horsley, et al., 2010). Since most standards-based reform efforts require teachers to change in some manner their current teaching practices, an essential resource for teachers during the implementation process is access to comprehensive professional development (Roehrig, Kern, & Kruse, 2008). To gain a better understanding of the types of supports teachers were using to increase their own knowledge and understanding of the NGSS, teachers were asked to respond to survey items related to availability and access to professional development (adapted from Ajayi, 2016; Banilower et al., 2013; Lumpe et al., 2000).

In this study, 100% (37 of 37) of the teachers agreed professional development was necessary and needed for the implementation of the NGSS (Figure 8). Additionally, 84.0% of the teachers agreed they would have access to professional development at their school site or in their district (Figure 8).

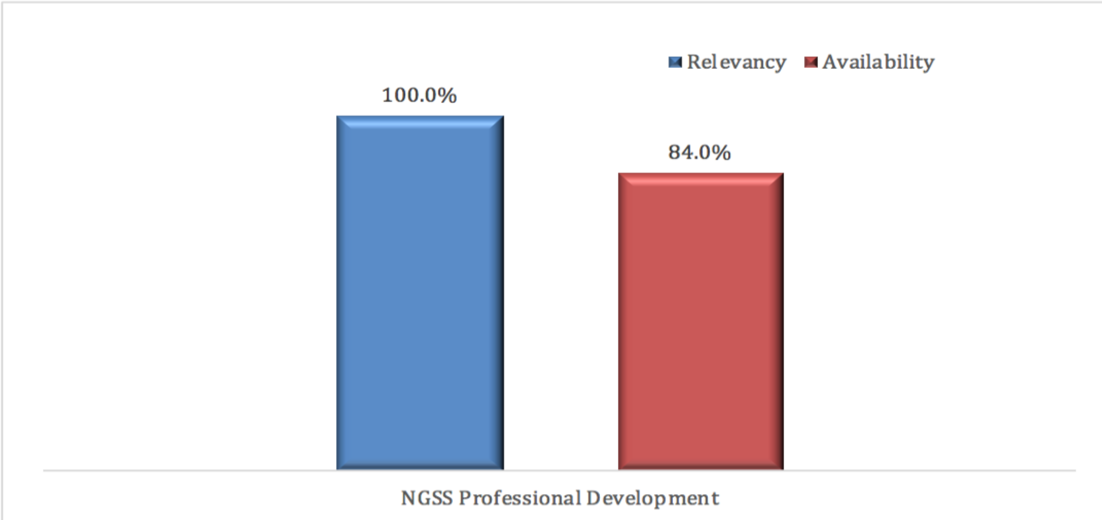

Figure 8: Professional Development: Relevancy. “Agree” teacher responses related to relevancy and availability of NGSS professional development.

To support this claim, survey items responses also showed 60% (22 of 37) of the teachers had attended between one and 35 hours of professional development related to the NGSS and 41% (15 of 37) had attended over 36 hours. The most commonly utilized sources of professional development were district workshops, site-based professional learning communities, and attendance at national and state conferences (Figure 9).

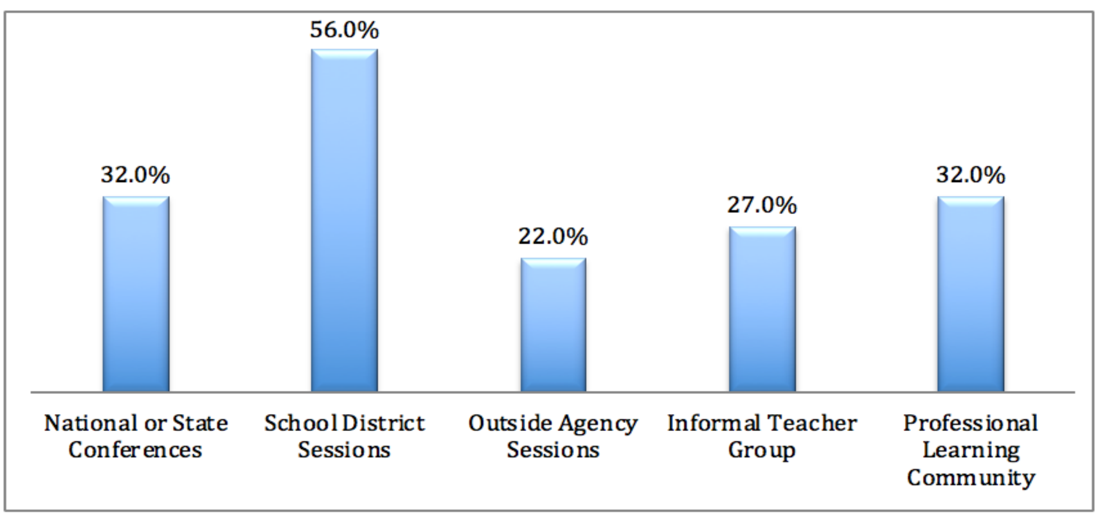

Figure 9: Professional Development: Session Types. Teacher responses related to the types of NGSS professional development they had attended.

Interview data also indicated that all eight participants had attended some form of professional development related to the NGSS. However, the types of professional development teachers utilized varied from teacher to teacher. For instance, Tanya had participated in professional development sessions sponsored by the county office of education:

> So, there was a STEM Symposium that the County Office of Education put on and that was huge…around 5,600 science teachers or something like that. Also the [county office of education science specialist] came up and trained us and had us do a couple activities.

Amy recently had attended a science summer institute put on by her school district:

> Most recently we had a science summer institute where they had planned three days, and they had hands-on activities. They really showed us what does it mean to do these kind of performance tasks or big picture.

Bianca remarked on how she had attended a professional development workshops sponsored by an outside agency:

> I was able to attend a two-week immersive modeling instruction workshop, and they gave out curriculum, and they gave out training.

Stephanie commented on her experiences with NGSS aligned professional development at national conferences and within her own district:

> My site administrator sent two of us to [name of national conference] in Los Angeles last year. I also think I was out of the classroom 10 or 11 days last year for NGSS. The pullout days were district wide. I was also able to attend some training last summer. Even though the summer training is only once every five years, it was good.

Based on survey and interview responses, teachers had accessed and participated in some form of professional development related to the NGSS in order to increase their own understanding and knowledge related to the NGSS.

Finding five. Even though teachers believed adequate professional learning opportunities were being provided to help them increase their understanding of the NGSS, gaps in teacher content knowledge still existed. Although survey and interview data indicated teachers felt they were receiving adequate professional development, additional study findings also suggested the need for more professional development for science and engineering practices and performance expectations. Moreover, findings from this study conflicted with the current research about professional development and teacher change.

First, research studies have found that teachers need 80 or more hours of professional development in order to put new teaching strategies into practice (Yoon, Duncan, & Lee, 2007). This is in contrast to the findings from this study, which indicated that 60% of the teachers had participated in 35 hours or fewer of professional development related to the NGSS. Second, teachers need intensive and ongoing professional development in order to support lasting change in classroom instruction (Moon, Michaels, & Reiser, 2012; Penuel et al., 2007). Yet, interview data from this study suggested teachers were often attending one-time or short-term professional development sessions. Lastly, professional development should be centered on building productive working relationships within academic departments or across content areas. This promotes greater consistency in instruction, more willingness to share practices and try new ways of teaching, and more success in solving problems of practice (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). Once again, this aspect of professional development was not apparent in the findings from this study.

In conclusion, even though teachers felt they were receiving adequate professional development related to the NGSS, more ongoing and sustained professional development will be needed to promote true change in instructional practices. Moreover, to ensure implementation consistency and fidelity, professional development should be a collaborative effort within departments or content areas, not isolated events teachers attend on their own.

Research question three. How have teachers begun to shift their instructional practices to align with the vision of the NGSS? What areas need additional support? Instructional practices are defined as the specific teaching methods teachers use to help students master curriculum learning objectives as defined by the state standards (Bybee, 2013). They can also be carried out by a variety of pedagogical techniques, sequences of activities, and ordering of topics (Jackson & Ash, 2012; Polikoff, 2013). Though the NGSS do not specify the types of instructional practices teachers are supposed to use in their classroom, teachers are expected to implement classroom activities and experiences consistent with the vision of this document (Bybee, 2013; National Research Council, 2015). In an effort to understand science teachers' pedagogical approaches in the context of the NGSS, the actions of both the teachers and of the students were gathered from the following survey and interview sections: (a) NGSS instructional practices (survey); and (b) NGSS preparedness and teacher change (interview). One finding associated with the third research question was identified and is discussed in more detail below.

Finding six. Although instructional practices are shifting to align with the vision of the NGSS, traditional practices are still prevalent and relied upon by the majority of the teachers. To effectively capture changes in instruction related to teacher and student actions, survey items asked teachers "how often do you do each of the following in your science instruction?" and "how often do your students do each of the following in your science classes" (adapted from Hayes et al., 2016). During the interviews teachers were asked questions about their current instructional practices and any changes they had made since the adoption of the NGSS. For ease of understanding, survey item responses and interview data were reorganized and are discussed as related to one of the five areas of instruction illustrated in Table 3: (1) traditional instruction; (2) engaging in prior knowledge; (3) empirical investigation; (4) evaluation and explanation; and

(5) science discourse and communication (adapted from Hayes et al. 2016). Where appropriate, the areas of instruction were also linked to the specific NGSS SE practice(s).

Table 3: Science Instructional Practices and NGSS Practice

Instructional Practice	NGSS practice	Definition
Traditional Instruction		Traditional teacher-centered approaches, including direct instruction, demonstration, worksheet or textbook work
Engaging Prior Knowledge		Engaging students' prior knowledge and real-world and home applications of science to bridge between science epistemologies and student experience
Empirical Investigations	1, 2, 3	Focus on investigative procedures: asking questions, determining what needs to be measured, observing phenomena, planning experiments, and collecting and analyzing data
Evaluation and Explanation	2, 4, 5, 6, 7	Focus on modeling, evaluation, and argumentation: constructing explanations, evaluating appropriateness based on evidence, fitting models, and critiquing ideas
Science Discourse & Communication	8	Opportunities for participation in scientific discourse that acculturates students into scientific languages and practices

Note. Adapted from Hayes et al., 2016

Traditional instruction. The traditional method of teaching is often defined as a teacher-centered delivery of instruction, whereby students are given information through direct instruction and information is reinforced through worksheets, reviews of vocabulary, and "cook-book" laboratory activities (Hayes et al., 2016). In an effort to measure shifts in science instructional practices, it was first necessary to gauge the current use of traditional instructional practices by teachers.

Survey data indicated teachers were still predominantly using traditional approaches in the classroom. As illustrated in Figure 10, 87.0% (32 of 37) of the teachers often used direct instruction to explain science concepts. Eighty-one percent (30 of 37) of the teachers often used worksheets to reinforce concepts and ideas, and 76.0% (28 of 37) often reviewed science vocabulary (Figure 10).

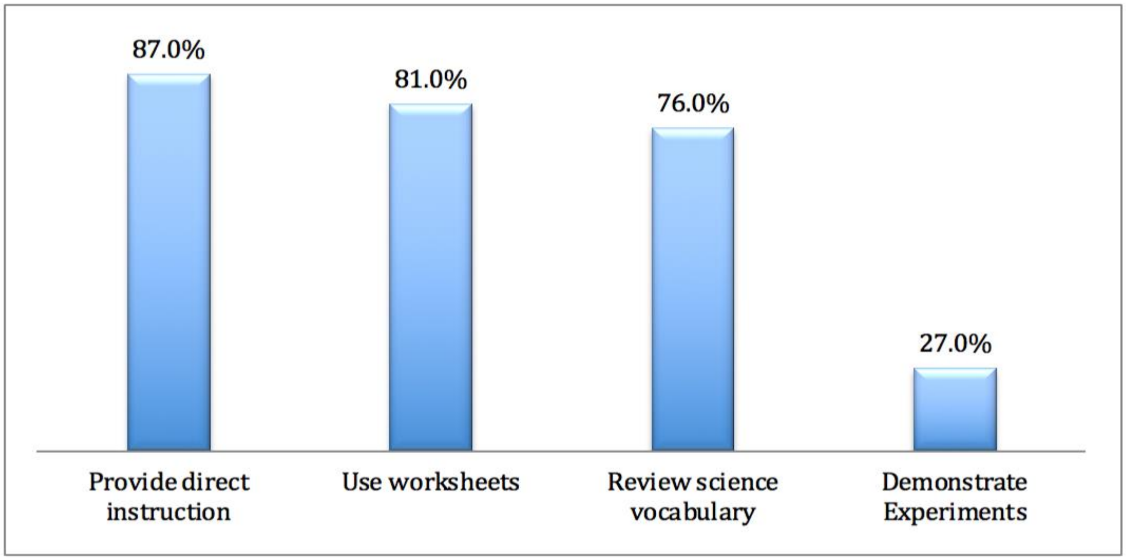

Figure 10: Instruction: Traditional Practices. “Often” teacher responses to the survey items related to classroom instruction.

Conversely, the traditional practice of the teacher demonstrating an experiment while students watched was not used regularly. As illustrated in Figure 10, only 27.0% (10 of 37) of the teachers reported they often used this strategy. Also of interest, statistical analysis indicated differences between how often teachers demonstrated experiments while students watched and years of teaching experience (p = 0.04, Kruskal Wallis H = 13.00, df=6;). As shown in Figure 11, Teachers with over six years of teaching experience recorded higher median scores than teachers with 0-5 years of teaching experience. Meaning, newer teachers did not report using this traditional approach to teaching as often as experienced teachers.

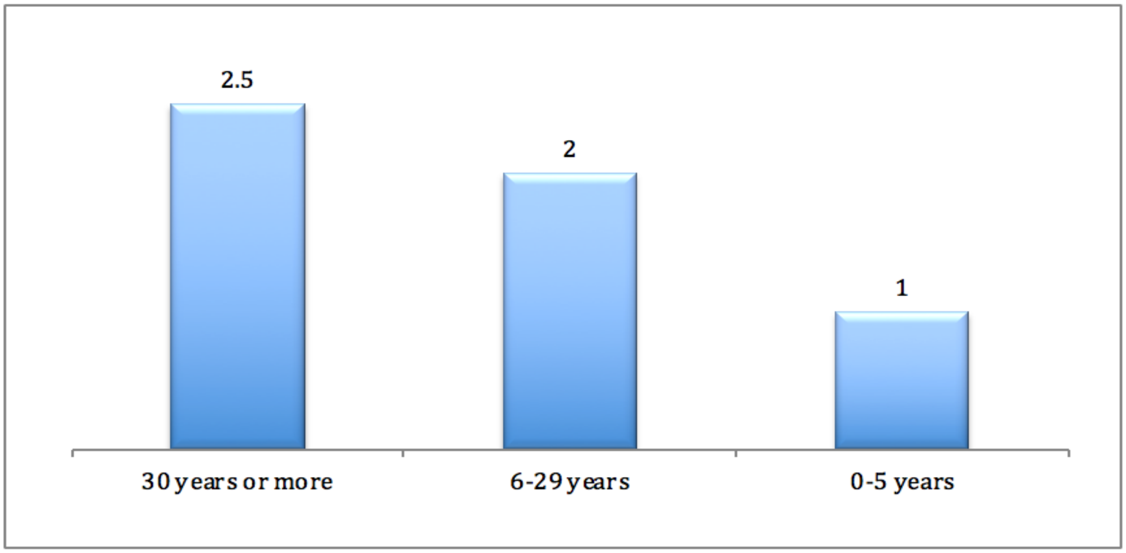

Figure 11: Traditional Practices: Statistical Analysis. Teacher median response scores by years of teaching for the survey item "Demonstrating Experiments".

Interview data also supported the idea that teachers were still using a more traditional approach to science teaching. This can be seen in how Amy described her instructional practice:

> At the beginning of the unit students take notes, then they complete some worksheets where they are practicing the information, then I sometimes have students do a lab. The lab is given to the students and they just have to follow the procedures, it's step-by-step.

Brianna stated she was using a more traditional style of science teaching:

> For the most part because I still haven't transitioned the class, a lot of it is the traditional model of teaching. I will give students copies of the PowerPoint notes and I them to add to it, or just read it and add their own notes, questions, and summary.

Tanya's practice also reflected a more traditional approach with a focus on classroom routines:

> It's all about routine. They come in, there's a warm up on the board having to do with what we've discussed last class to get their brains remembering what we did last time. Then, I'll go into a lesson, lecture, where they take notes, we have discussions. After that, an activity, there's an activity, or independent work.

Combined, survey and interview data indicated teachers were still primarily using traditional pedagogical practices in their classrooms. These practices included the use of direct instruction, worksheets or bookwork, and a focus on science vocabulary. However, in regard to the use of traditional practices, statistical analyses also revealed some instructional shifts have started to occur.

This finding was important, because studies related to policy reform implementation have found that it is unrealistic to expect teachers to completely transform their instruction all at once or over a short period of time (Bybee, 2013; Johnson, 2006; Mundry, & Loucks-Horsley,1998; National Research Council, 2015). Rather, teachers need multiple opportunities to learn, practice, collaborate, and use any new skills (Johnson, 2006; Mundry, & Loucks-Horsley, 1998). Thus, changes in instruction that are called for in the NGSS will not only take time but will most likely start with smaller shifts as teachers become familiar with these new practices (Fullan, 2016; Loucks-Horsley et al., 2010; National Research Council, 2015). In an effort to measure these smaller shifts in instruction, survey items and interview questions captured information related to a subset of instructional practices: (1) engaging in prior knowledge, (2) empirical investigation, (3) evaluation and explanation, and (4) science discourse and communication (adapted from Hayes et al. 2016; see Table 3).

Engaging prior knowledge. Engaging in prior knowledge is based on the idea that by engaging students' prior knowledge and using real-world applications teachers can link student experiences to science concepts and practices (Hayes et al., 2016). As shown in Figure 12, 89.0% (33 of 37) of the teachers often used science concepts to explain natural events or real-world situations. Similarly, 76.0% (28 of 37) of the teachers often related science topics to a student's prior knowledge and 70.0% (35 of 37) connected science concepts to practices at home (Figure 12).

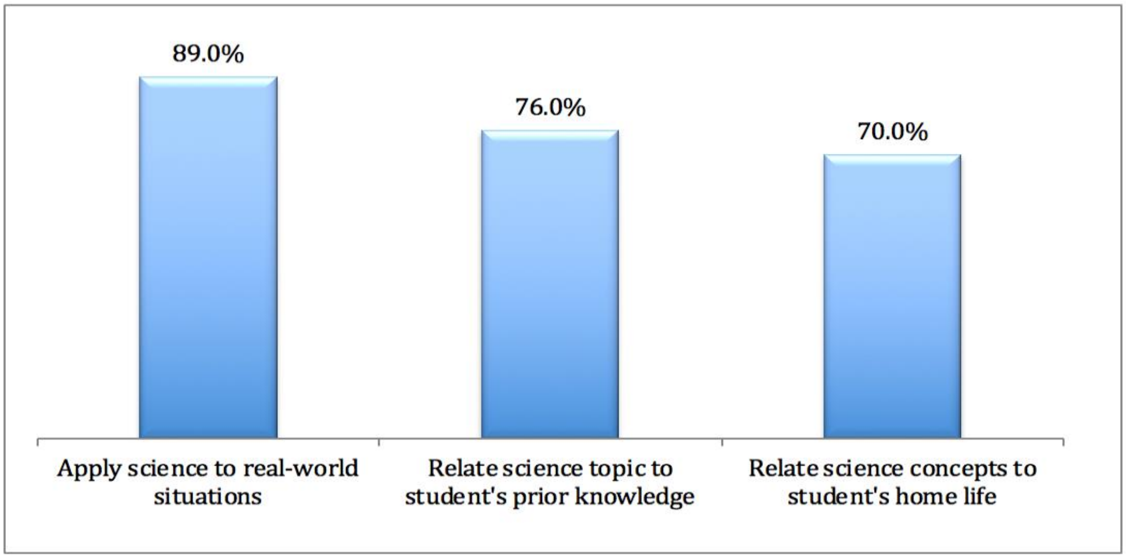

Figure 12: Instruction: Engaging Prior Knowledge. "Often" teacher responses to the survey items related to the practices of engaging prior knowledge.

Interview responses also indicated that for some teachers, engaging a student's prior knowledge was a new practice for them. For instance, Katherine talked about how pre-NGSS her classroom practice focused more on breadth of content and less on depth:

> I covered a lot more pre-NGSS, but I will tell you that there wasn't as much in-depth. I really focused a lot on literacy, reading comprehension, interpretation, and application.

Yet, she has now started to incorporate some new instructional strategies such as the use of phenomena to start a lesson:

> A typical start to a unit now would be introducing students to phenomena and having them investigate and explore on their own. There's no lecture, I'm not telling them the answer. They get to manipulate on their own, they get to discuss with their peers, and I do what's called, they work through a mental model. They diagram, they write a little bit about this phenomenon as scientifically as they can.

Similarly, Bianca described how she started her lessons: "They always start off with a launch where I show them something cool, like a ball dropping, or a pendulum swinging, or a car moving."

Empirical investigation. Science education literature emphasizes the need for students to conduct "empirical investigations" as a means to build knowledge in science (Bybee, 2011; Hayes et al., 2016; National Research Council, 2012). While this is not necessarily a new idea in science education, prior to the NGSS, science investigations and activities were frequently used only to reinforce already learned science concepts and ideas (Bybee, 2011). In the era of the NGSS, however, students will now be expected to design their own empirical investigations, collect and analyze data, and then use their evidence to construct, critique, and defend scientific arguments (National Research Council, 2012). The use of empirical investigations in the classroom are linked to the following NGSS SE practices: (1) NGSS SE Practice 1 (what needs to be measured); and (2) NGSS SE practice 3 (observing phenomena, planning experiments, and collecting data) (Hayes et al, 2016; National Research Council, 2012).

Survey item responses indicated that teachers had started to shift from the more traditional "cook-book" laboratory exercises to activities that required higher student participation and cognitive demand. As seen in Figure 13, 54% (20 of 37) of the teachers reported that they often had students generate questions or predictions prior to beginning an investigation, and 38% (14 of 37) used some sort of phenomenon to generate these questions and predictions. However, only 11.0% (4 of 37) of the teachers had students design and implement their own science investigations, a practice that will need to become more commonplace in order to realize the vision of the NGSS.

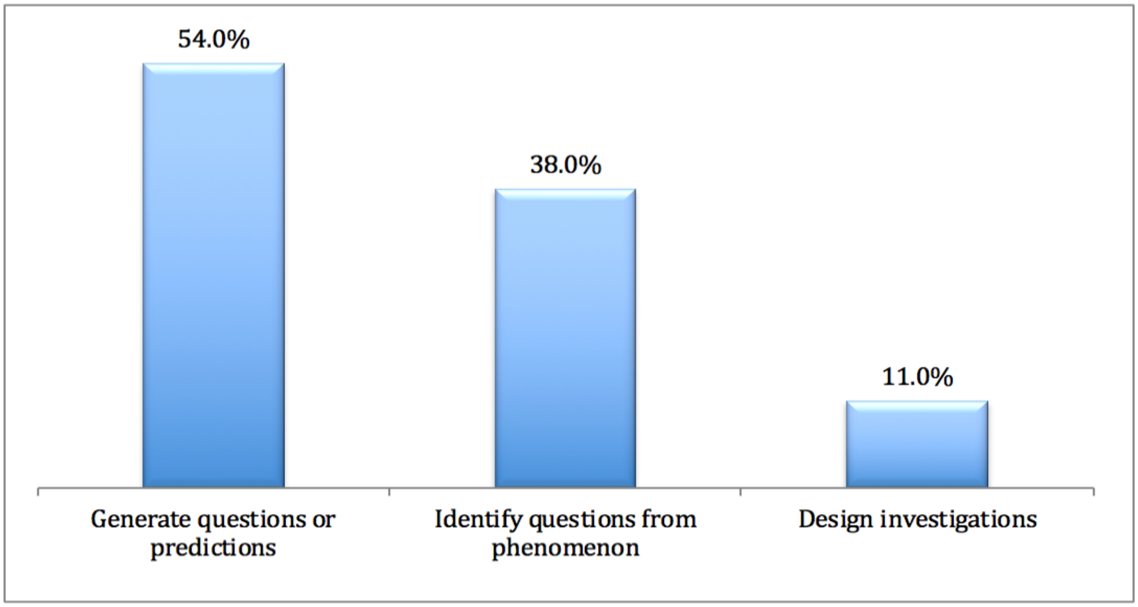

Figure 13: Instruction: Empirical Investigations. “Often” teacher responses to survey items related to implementing empirical investigations in the classroom.

During interviews, teachers were also asked about the use of science investigations in their classroom. Two teachers had started to move away from the traditional “cook-book” laboratory exercises to activities that required higher student participation and cognitive demand. For example, Brian described an activity he had used recently in his Biology class:

> So, to start my biochemistry unit, I put a bunch of different macromolecules, ballistic method drawings, and other illustrations on a piece of paper in random order. I then walk around the classroom and ask students, “If you were going to organize these, how would you put these together?" Then they start questioning each other, “Well, why did you put this here, that doesn't go there, that goes over here.” This then leads very naturally into us having a conversation about the topic, and then I have the students go prove what they are thinking.

Bianca also commented on her approach to science investigations:

> I show them some event, and we record our observations. We record how we can measure certain things about that event, like speed, or time, or position. And then I throw them the problem statement, which would be, "Okay, let's look at how these two items and how they relate to each other." And then they have anywhere

> from 20 minutes to an hour and a half to plan, and then carry out the investigation, in order to determine the relationship between those two things.

However, it is unclear from these findings if this was a result of the NGSS or a preference in teaching style. For example, Brian stated that he really had not changed his instructional practice too much because his instruction was already aligned to the NGSS due to his experience in AVID. Similarly, Bianca stated, "since I am a fairly new teacher I have been teaching using the NGSS all along and do not know any other way to teach."

Evaluation and explanation. Evaluation and explanation practices typically involve students generating and using models, analyzing data, constructing explanations and evaluating appropriateness based on evidence, and then using the evidence for argumentation and critique (Hayes et al., 2016; National Research Council, 2012). These practices are linked to the following NGSS SE practices: 2 (generating and using models); 4 and 5 (quantitatively analyzing data); 6 (constructing explanations and evaluating appropriateness based on evidence); and 7 (argumentation and critique) (Hayes et al., 2016; National Research Council, 2012).

As illustrated in Figure 14, 60.0% (22 of 37) of the teachers reported they often had students explain their reasoning behind an idea and analyze relationships using charts or graphs. Forty-three percent (16 of 37) of the teachers also stated that they had students make arguments to support or refute a claim. Approaches that focused on having students develop or create their own models were used less frequently. Only 11.0% (4 of 37) of the teachers indicated that they often had students create models based on scientific phenomena and 22.0% (8 of 37) indicated that they often had students create a model based on their own data or observations.

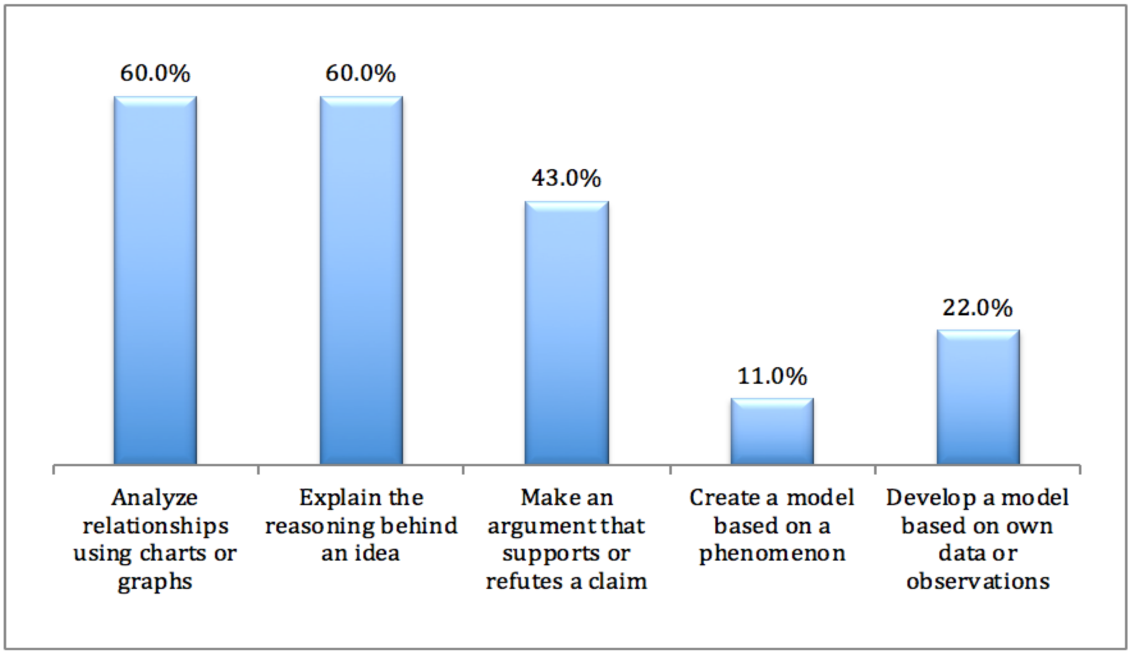

Figure 14: Instruction: Evaluation and Explanation. "Often" teacher responses to survey items related to implementing evaluation and explanation practices in the classroom.

Statistical analysis also indicated a difference between males and females with regards to having students create models of a scientific phenomenon ($p < 0.05$, Mann-Whitney $U=92.00$, $Z= 1.97$). Female teachers were more likely to have students create models than male teachers. The strength of this relationship between gender and confidence level was medium ($r = 0.55$).

Similar to findings related to the use of empirical investigation practices, Brian and Bianca's interview comments indicated that they had started to implement some evaluation and explanation practices in their classrooms. In particular, having students explain reasoning behind an idea and making an argument that supports or refutes a claim. Teachers did not mention the use of models during the interviews.

Science discourse and communication. The use of science discourse and communication in the classroom promotes opportunities for students to use scientific language and also increases student understanding of scientific ideas and practices (Hayes et al., 2016). These practices are linked to the NGSS SE practice 8 (obtaining, evaluating, and communicating information) (Hayes et al., 2016; National Research Council, 2012).

Survey item responses and interview data suggested the most common teacher actions in this area involved having students working in small groups and supporting student to student discourse about science concepts. As presented in Figure 15, survey item responses indicated that 92.0% (34 of 37) of the teachers often had students working in small groups and 76.0% (28 of 37) of the teachers often encouraged students to explain concepts to one another. Seventy-three percent (27 of 37) of the teachers also reported using open-ended questions to stimulate whole class discussions (Figure 15).

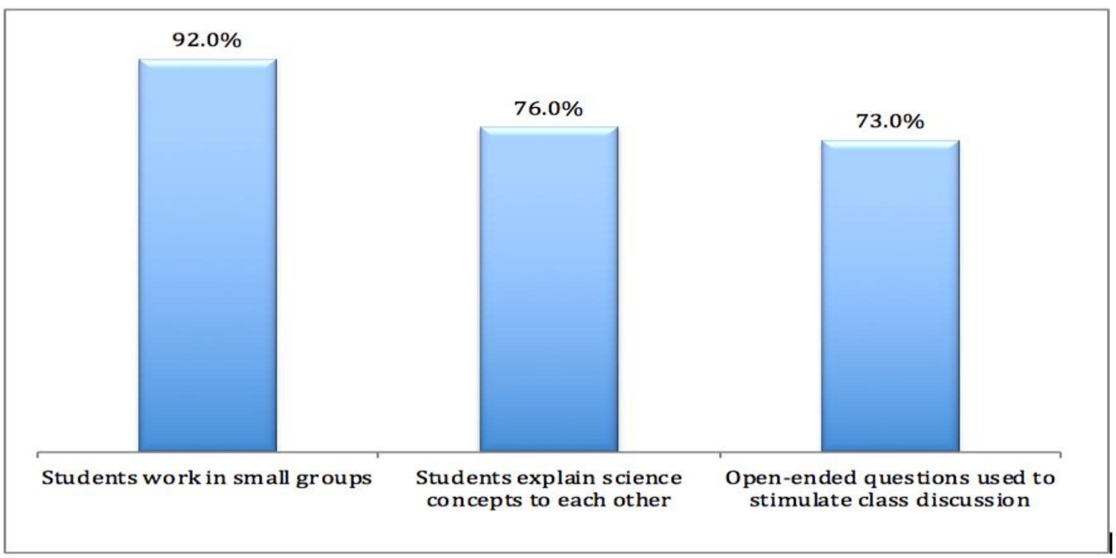

Figure 15: Instruction: Science Discourse. "Often" teacher responses to the survey items related to implementing science discourse and communication practices in the classroom.

Likewise, when teachers were asked during the interviews to describe the types of strategies they most often used to promote student discourse, the most frequently mentioned practice was student small groups. Gabe described how he rearranged his classroom to promote more group work and student talk:

> So now my chairs are arranged in groups of four and they are arranged in a way that everybody kind of looks at each other…they have no choice. This way it is easier to do more pair share or group work…I can also go around and ask them to pick a spokesperson for their group. We also do a lot more white-boarding…it's easier with them in groups of four.

Stephanie commented on how she was using more open-ended questions to promote student learning:

> I'm trying to scaffold by starting off with questions that relate to our topic. Like the whirligig lab I am doing next week in all the physics classes, I'll drop a whirligig and say, "Okay what can we measure if we want it to stay in the air longer? What can we do?"

However, while several of the teachers mentioned using open-ended questions to promote student to student discourse, they also admitted this was the area where they needed the most support. Katherine remarked on her struggle with getting students to talk:

> Just getting them to ask questions and talk to one another. I just don't know…I don't know…how to I do that every day?

Amy discussed how she felt it was going to be hard for her to come up with questions:

> Coming up with questions to ask students is going to be hard for me. As a teacher it is easier to just give information, and give them a lab, and then a multiple-choice test. It is going to be a lot of work…a lot of planning.

Tanya also had concerns about coming up with questions and creating opportunities for student talk:

> Coming up with questions. That's going to be the tough part for me. Finding something they are interested in, that they can have a discussion with their classmates about, and try to figure things out, that is going to be hard.

Combined, survey responses and interview data indicated that teachers had started to make small shifts in their instructional practices aligned to the NGSS. The most common approaches appeared to be the use of a phenomenon to launch a lesson; using questions to promote whole group discussion; arranging students to work in small groups; and having students explain their reasoning behind an idea. Statistical analysis also indicated a difference between males and females in regard to having students create models of a scientific phenomenon, with female teachers more likely to have students create models than male teachers. This suggests a need for further investigation into the relationship between teacher gender and implemented teaching practices.

Research question four. What factors are influencing teacher sensemaking and implementation of the NGSS? What are some perceived barriers? In the field of education, sensemaking enables researchers to understand how teachers develop an awareness of reform messages and build understandings of them through their preexisting practices and cognitive frameworks. For instance, sensemaking has been used to better understand how teacher practices are changed through collective sensemaking, whereby a teacher makes sense of a policy through interactions and discussions with colleagues (Coburn, 2001). The sensemaking framework has also been used to elucidate the interaction between teacher knowledge, beliefs, emotions, and their interpretation and enactment of policy (Schmidt & Datnow, 2005). Other studies have used the sensemaking framework to gain better insight into how school environmental factors such as curriculum, supplies, and administration influence teacher implementation of reform polices (Park & Oliver, 2008). For these reasons, a sensemaking framework was used to unpack and describe the factors that were influencing and hindering teacher implementation of the NGSS. In the current study, factors that were influencing or hindering implementation of the NGSS were gathered from the following survey and interview sections: (a) NGSS beliefs (survey and interview); (b) NGSS implementation resources and supports (survey and interviews); and (c)

NGSS preparedness and teacher change (interview). Two primary findings associated with the fourth research question were identified and are discussed in more detail below.

Finding seven. The practice of consistent engagement with other teachers in an effective collaborative environment positively influenced teacher sensemaking and implementation of the NGSS. In working to meet the mandates of any reform policy, teachers often seek effective, meaningful collaboration with other teachers to increase their own expertise. In fact, researchers studying reform implementation processes have acknowledged that teacher networks can play an important role in teacher learning and organizational change (Coburn et al., 2013; Datnow, 2012; Loucks-Horsley & Matsumoto, 1999; Mundry, & Loucks-Horsley, 1998). Primarily, teacher networks afford teachers the opportunity to exchange ideas, interpret policies, construct shared understandings of new policies, and in turn adjust their own professional stances on their teaching goals and practice (Coburn, 2001; Coburn, 2006). To further explore the relationship between teacher networks and reform implementation processes, during the interviews teachers were asked questions concerning their collaboration with other teachers. For example, Bianca was in her fourth year of a fellowship program that she consistently referenced as helping her deepen her understanding of the NGSS:

> I completely credit my fellowship, which I was awarded my first year of teaching. There was an old science teaching foundation fellowship. There was an application process at the beginning of my student teaching, and a couple interviews, and then I was accepted into the program. And it's a cohort of 30 science and math teachers from across the country, and we meet three times a year, and we have mentors through that program, called teacher developers. And it's a five-year fellowship, so I'm going into my fourth year now. We have a fall, spring, and summer meeting. At each meeting we do sessions and workshop on professional development on NGSS.

In addition to her association with the fellowship program, Bianca also sought out other opportunities for collaboration within her district and at her school site. Bianca commented on collaborating with another new science teacher in her department:

> I used to work by myself. I was hungry to work with other teachers, but it was hard for me to find someone. Now I work with [name of teacher]. She was hired last year and also just came out of the credential program, so she understands it the way I understand it.

She also mentioned working with the district science coaches or teachers on special assignment (TOSAs):

> I've been able to call them up, which has been really nice. I forgot what it was, but it was twice that I really needed an answer to something, or I needed perspective, or help with something in the lesson, and I was able to call them up and they were available. That was really nice and helpful.

Because of these collaborative structures Bianca stated she felt well prepared to implement the NGSS, saying "I feel as prepared as I can be…I can name off all the science and engineering practices, crosscutting concepts." She also described how her classroom instruction and assessments were aligned to the NGSS:

> Yeah, usually I'll start up with some sort of opening activity that reviews previous class materials. And then I'll model a practice, or a skill, or a concept that I want them to master. We practice it as a group, and then they have the individual practice. And then in closing there's usually some type of reflective activity after they've had some time to practice on their own.
>
> Yeah. I offer multiple opportunities to demonstrate mastery. So something that I let students know what they're expected to do is to always try their best. And it's expected that not everyone gets it the first time. And if it takes them trying the quiz, or the test, or an assignment, a problem set, two, three, four times to really get it right, then let's do that. Let's take advantage of that. And I don't deduct points for late work, I don't deduct points. So if I know students are more often motivated by grade, I'll make that point that your grade won't be affected negatively if it takes you a week longer to master this skill or concept than someone else.

Brian also described his partnership with another teacher and how it had contributed to his understanding of the NGSS:

> So when I came to this school a couple of years ago, there was a heavy emphasis on the traditional…And when I came in, that's not the environment that I'm coming from. At the middle school I was really focused on the NGSS philosophy…but I got hired literally two days before school started. So I pretty much followed a script for two years but it did not feel right. But this last year, [name of teacher] who also teaches biology, we have really connected and really clicked and she's all for it, and so we went to some training together and…we got together and spent some time last summer and started writing curriculum, and we got, basically, about a third of the year worked out at that point. And then we always kept about a month ahead of ourselves. We continued to try stuff and keep notes on ourselves about, "Hey, this worked out well, this didn't work out so well."

Brian had also been affiliated with AVID for over 17 years as a teacher trainer and while it was not necessarily professional development for him, the consistent dialogue about the NGSS helped him to increase his own knowledge and understanding:

> I'm a trainer for AVID, I'm a science trainer for AVID and so I do the summer institutes and path trainings during the year and so we do the NGSS…because NGSS is present and growing it's something that we, especially in the last two years, we have started weaving into the summer institute. So people understand that how AVID strategies really dovetail with what's going on…I understand much more now.

From these experiences Brian also felt prepared to implement the NGSS:

> Yeah, I'm ready to go. I personally feel at this point right now; I feel like I'd give myself an eight out of 10. Like I know how this stuff works and I know where we're going and I have a foundation to work form.

To help her make sense of the NGSS, Katherine described how she benefitted from being on the district science curriculum team for the past year:

> Our district started, it's called OER, Open Educational Resources, and they created these teams. Last year, they had enough to create a biology team…I was on that committee and it was pretty intense. It's going again through next year. I think that process has really helped me, really helped me understand the standards and how they look in a classroom.

Katherine was also the professional learning community (PLC) lead for her biology team and described how her PLC had been able to effectively collaborate and discuss the NGSS:

> I'm the bio team lead, so what I try to do in our collab [sic] time, every Wednesday we have collaboration…So what I try to do is focus on things that we can use…like, literacy. What are the reading strategies we're using? How are we incorporating, we have such a high EL population, how are we incorporating our ELD standards? Most of us are on the same page. I would say that in terms of really tackling our pacing guide, and really making it 5E and NGSS, I think I probably took the lead on that, because I just saw the benefits of it in my classroom. So, I think I was able to sell that to them I think they're all on board.

Katherine's participation in these effective collaborative structures not only increased her understanding, but also caused her to start changing her instructional practice. For instance, Katherine talked about how pre-NGSS her classroom practice focused more on breadth of content and less on depth:

> I covered a lot more pre-NGSS, but I will tell you that there wasn't as much in-depth. I really focused a lot on literacy, reading comprehension, interpretation, and application.

Then she described how she had started to incorporate new instructional strategies from her work on the district curriculum team:

> A typical start to a unit now would be introducing students to phenomena and having them investigate and explore on their own. There's no lecture, I'm not telling them the answer. They get to manipulate on their own, they get to discuss with their peers, and I do what's called, they work through a mental model. They diagram, they write a little bit about this phenomenon as scientifically as they can.

Combined, the described experiences of Bianca, Brian, and Katherine demonstrate that regular engagement with other teachers in a collaborative environment can positively influence teacher sensemaking and implementation of a new reform policy.

Finding eight. Teachers felt school administrators, ineffective collaborative structures, and the shortage of resources, could hinder their ability to effectively implement the NGSS. Research in the field of education has demonstrated that individual teachers can be change agents in their own classrooms, but they often have varied success due to internal and external barriers that impact their translation of new instructional strategies into practice (Anderson & Helms 2001; Fullan, 2001). Previous studies have identified three main types of barriers teachers implementing new reform efforts often encounter: technical barriers, which can include lack of time for planning, instruction and collaboration, as well as inadequate professional development; political barriers, which include lack of administrator support, as well as lack of curricular and instructional resources; and cultural barriers, that mainly focus on teacher beliefs and perceptions about teaching (Johnson, 2007a). In this study, to gain a deeper understanding about the relationship between external barriers and the implementation of the NGSS, survey items asked teachers to "rate how necessary various elements were to the NGSS implementation process, as well as the likelihood of it being provided in their district or school site" (adapted from Ajayi, 2016; Banilower et al., 2013; Lumpe et al., 2000). Teachers were also asked during the interviews about the types of supports or opportunities they had been provided at their school site or district. Based on survey item responses and interview data, the following factors were negatively impacting the translation of the NGSS into practice: (1) school site administrators; (2) professional learning communities; and (3) lack of resources.

School-site administration. Research on the principal's role in school reform suggests that principals have a strong influence on how teachers make sense of and implement new policies. Primarily, a principal can increase a teacher's sense of trust and security by helping provide a supportive, fair, and cooperative school environment along with established time for collaboration and reflection (Spillane et al., 2002). In this study, 89.0% (33 of 37) of the teachers agreed they needed support from their school site administrators if they were to effectively implement the NGSS. However, only 60.0% (22 of 37) of the teachers agreed they were receiving this support.

Similarly, teacher beliefs related to their school environment, in particular the need for trust and respect between teachers and the school administration, was a reoccurring theme in the interview data. Brianna recalled incidents that diminished her trust in the school administrative team, due to a perceived lack of commitment to science education:

> We have tried to get them to encourage students to take a science as a freshman. We as a department have tried to encourage them to have students take a science as a freshman. But it seems like they don't listen to the students or teachers. Our administration doesn't want to push them into science. They told counseling not to push them into science as a freshman.

Similarly, Gabe felt his school administrators were not committed to science education because they were not making the time to understand the NGSS:

> [Administrator name] is our admin for science, but he doesn’t know anything about the NGSS, nothing really. Our admin has no clue about NGSS. We would like our leadership to work on it, because we are already in year three of the NGSS. It's like, if we're doing these things, how does our admin even know what we're doing? How can they even evaluate us 'cause they don't even know if what we're doing, if it's right or wrong or if I'm being a really good science teacher? What about Joe-Shmo who is still stuck back in the 2000 standards and he's doing a disservice to our entire school. But they don't even know what's what, you know what I mean?

Other teachers felt a lack of support due to school-site leadership intrusion in their PLCs. Amy described how her school administration supplanted the time she and her colleagues had in their PLCs by assigning various tasks teachers needed to complete during that time:

> I would say support that I need is...If we can actually have some PLC time, some time with the teachers so that we can design the units together. We have an hour a week where we are given time, for the most part...Sometimes it's department time. We have about an hour a week...But what ends up happening is when admin tells us what we need to do in that hour, then all of a sudden we're doing that instead of being able to meaningfully plan. I'm a biology PLC lead for this next year, and that was one thing I'm really going to try to do that I told the other biology teachers is...Whatever admin is telling us what to do, goals or whatever, a special

> assignment they want us to do, I told them that I would try to answer those questions or fill out that paperwork outside of our PLC time so that we can actually use our PLC time to plan and figure out what phenomenon and try to work together a lot more. In the leadership meeting, we've said that we would like time to work on what we want. And there is always this, "Oh yeah, you guys have your three PLC meetings a week." But then we'll get an email that says you need to do this, this, this, and this...And so it seems like we spend the first half an hour doing whatever little assignments we get from admin to where...Then all of a sudden we have less time to really have meaningful conversations.

Stephanie and Tanya also commented on the lack of time to collaborate in their current school structure. Stephanie stated, “We would like to have the same prep period.” Tanya commented, “I would like more collaboration time. The time to collaborate and brainstorm is really what we need right now.” Teachers also felt that if their site administrative teams really supported them they would reduce science class sizes. Tanya commented:

> For one teacher with a class of thirty-five, forty kids, doing these, all these open-ended experiments or the groups are doing their own thing. It's a lot on the teachers to go around and make sure each is working and making progress and all of that. It's kind of the whole, “how do I do this on my own?”

Brian expressed similar concerns:

> Well, the class sizes are big too. 38 is what the agreement is right now? 38 to one. And so you kind of go, well, read between the lines, I'm thinking here now when we have our department meetings, I know that there's been some frustration expressed at the...we're quite heavy in social sciences at our school and it seems that every time, this is only hearsay, a retiree happens to be a social studies they replace them. And our department chair has given me the idea that he has always pushed as soon as one of them retires. We want to hire another science person because we have a relatively small science department compared to social sciences. Social sciences, 20 something teachers and we're like 11, 12.

In sum, teachers identified needing their site administrators to have a better understanding of the NGSS and the types of supports needed to effectively implement the NGSS. However, teachers were not optimistic about receiving more resources or support due to conflicting beliefs about the importance of science education.

Professional learning communities. The idea of increasing teacher learning and improving instructional practices through the use of school site professional learning communities (PLCs) has been a trend in education for some time. Moreover, research has shown that these collaborative structures can influence collective understanding of external initiatives (Coburn, 2001; Honig & Hatch, 2004; Spillane et al., 2002) as well as teaching practice (Coburn, 2001) and organizational learning (Bryk et al., 1999). Survey item responses indicated that 92.0% (34 of 37) of the teachers agreed they needed support from other teachers and 78.0% (29 of 37) agreed this resource would be available to them. However, when teachers were asked during the interviews to elaborate on this topic, seven out of the eight teachers stated their PLCs were not conducive for learning or support. As Brian stated, "we'll meet as a department then we'll break into our PLCs, but not a lot gets done." Amy, Brianna, Bianca, Stephanie, and Gabe all had similar comments. Amy felt her PLC was dysfunctional:

> We have about an hour a week. I'm the biology PLC lead for this next year…I want to use our PLC time to plan and figure out what phenomenon and try to work together a lot more. I would say our biology PLC team seems to be a hard group to try to get everyone on board. We're kind of dysfunctional. We have some teachers that are kind of set in their ways and that aren't really interested in getting together as a group. They kind of want to do their own thing…it's frustrating.

Brianna described how by the end of the school year she was not even a part of an operating PLC:

> Every other week we have PLC time. There were four teachers last year that taught Oceanography and Earth Science. Two of the four didn't believe in PLC so it was completely dysfunctional trying to work with them on anything. They refused to work with anything. So me and the other teacher started an Oceanography PLC, but about three months in she decided she wanted to go with Biology. Biology was going to be implementing NGSS this upcoming year and she didn't want to be missing out. So I get that. So sometimes I sit in on the Biology PLC just because I have nowhere else to go. And they talk about Biology stuff.

Bianca stated her PLC was not a very cohesive group:

> So a lot of different attitudes, and it was hard for me to find someone, until [name of teacher] really, who also came out of the credential program, which understood it the way I understood it. So I think a lot of different perspectives mixed in together, and that made it really hard to see eye to eye with anyone.

Stephanie indicated her PLC did not meet due to fighting amongst the teachers:

> We have collaborative Mondays like three months out of the week, or three weeks out of the month are collaborative Mondays, and then we can have a PLC, but the last two years were almost non-existent because we had some department infighting, so I didn't have my chemistry PLC, and then it's just me for physics. So every opportunity the district gives me, I take, because that's the only way that I get to improve my teaching.

Gabe mentioned he was disappointed in how his PLC functioned:

> Right now our meetings run like this: we get together, they typically tend to be... where are you guys at with your curriculum, where you at with our curriculum, so then it's a conversation about like, how tired we are, and then it's a conversation about, I'm really behind I need to catch up, and then it's a conversation of, well what are you gonna do next week and then...but there's no real like planning or strategy. A lot of times we get in there and it's like, "You got a lot of grading too?" "Yeah, you got a lot of grading to do?" "Let's just call it a meeting and let's finish our grading." Most times it's a very quick meeting. It's appointments.

As mentioned previously, Katherine was the Biology PLC lead, and was the only teacher who felt her PLC meetings contributed to her understanding of the NGSS.

These findings support the idea that teachers need access to effective and collaborative learning environments in order to implement the NGSS. Yet, many teachers do not have access to these collaborative structures, which in turn can limit their ability to understand and make sense of any new reform initiative.

Lack of resources. Research in science education has established that teachers often interpret new policies in relation to the availability of resources such as equipment, consumable supplies, curriculum, instructional materials, and time for planning (Johnson, 2006). Relatedly, a recent study by Haag and Megowan (2015) also illustrated that while teachers were positive about implementing the NGSS, teachers were also anxious about inadequate resources, which in turn was negatively impacting their implementation of the NGSS. As presented in Figure 16, survey item responses showed that 84.0% (31 of 37) of the teachers felt their school district should adopt an official NGSS curriculum, but only 43.0% (16 of 37) were optimistic these resources would be provided. Correspondingly, 73% (27 of 37) of the teachers indicated they would like to have district-adopted science resources such as textbooks and laboratory manuals, but only 35.0% (13 of 37) of the teachers thought these items would be provided (Figure 16).

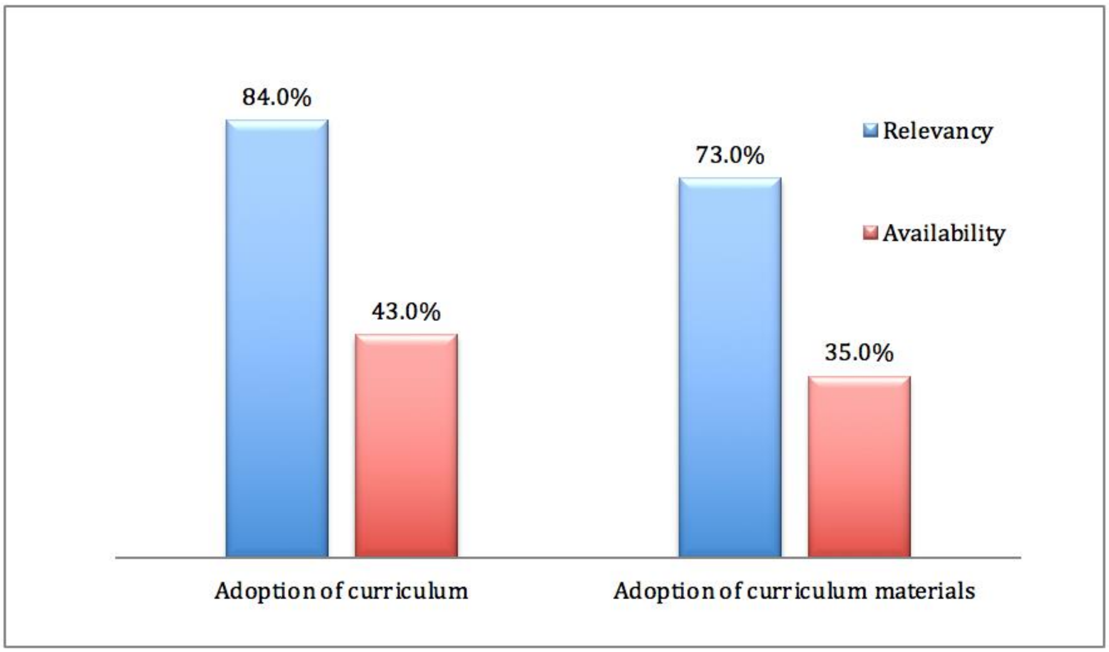

Figure 16: Resources: Curriculum and Materials. "Relevancy" and "Availability" teacher responses to survey items related to NGSS resources.

Open-ended survey responses also revealed that teachers felt the adoption of an official science curriculum and resources in their district were necessary for the implementation of the NGSS. As one teacher stated:

> My school district does not directly tell each school what curriculum to teach or what science class to teach particular strands of the NGSS. Each school makes their own decisions and the teachers decide on the curriculum. Very little

> oversight is causing the NGSS to be implemented in a loosely constructed manner. We need more concrete lesson ideas.

To further clarify how the perceived lack of curriculum and materials were impacting the implementation of the NGSS, in the interview portion of the study teachers were asked to explain their thoughts about the availability of curriculum and resources in their own district. Interview data indicated that teachers in the Hidden Valley Union High School District had access and were expected to use the district adopted science curriculum. But, textbooks and other ancillary materials were not being provided. Correspondingly, teachers in the Hidden Valley school district did not feel curriculum was a barrier; rather it was the lack of textbooks. For example, Amy felt she needed textbooks in order to implement the new standards:

> I need concrete examples of what can I physically do. And right now, I think it's kind of tough because it's new, and so there aren't a lot of instructional materials out there. There's no textbook for us right now. There's nothing that can give you ideas. I'm interested to see what kind of educational materials are going to come out there to help teachers. Because you can talk all day about how this is new, but if you don't actually see how it's new and how it's different, then you still just fall back into what you were doing before.

Similarly, Brianna did not see how curriculum could be adapted for the NGSS without a new textbook:

> Our textbook is 12 years old. So we know that there will be another adoption and trying to re-do the curriculum with an old textbook just doesn't make any sense.

In comparison, teachers in the Lincoln Union High School District had access to district approved online educational resources (OER), but they were not required to use them in their classroom. Instead, individual school sites and teachers were given autonomy to develop and implement their own curriculum and materials. In turn, some of the teachers from the Lincoln school district did not think the OERs were “true” curriculum, and wanted the district to adopt an official curriculum with aligned textbooks and materials. In addition, in the absence of these materials, teachers were individually deciding what curriculum and materials to implement in their own classrooms. For example, Katherine stated she was using the district online educational resources in her classroom:

> You go to the website and then you can click on a topic and it takes you to a page that has resources broken down by readings, or labs, assessments, phenomenon, guiding questions. Then on that page, is a link to a sample 5E lesson plan that's been completely done, starting with your engage explorer. Then with that, is what PE that aligns to, what DCIs, and crosscutting concepts it’s supporting. Then there's also what Common Core and what ELD standards are you covering for the whole unit. It's pretty intense. It's pretty elaborate. A new teacher comes in, it’s like boom, you have the whole lesson with resources and materials and it’s already aligned to the NGSS. I used the lessons that we created, because I felt that they were great.

Gabe, on the other hand, was not using these resources because he was not convinced it was actual curriculum:

> So you know [Lincoln Union High School District] is very autonomous. The big push right now is for the [science curriculum team] to create an online resource... which I guess they have…so you kind of click on a chapter like photosynthesis and it opens all these items, like videos on Photosynthesis and so it's kind of like teacher vetted. So that’s all it is really ... It's not curriculum, not necessarily curriculum per se. You could use stuff, like they might post, oh here's a lab for photosynthesis, or here's two to three labs, so you could turn it into curriculum but it's not quote unquote, “Curriculum.” So, that's the district's big push right now and we're one to one. So, they're trying to do everything they can to incorporate the Chrome book.

Instead of using the district resources, Gabe found curriculum through other online resources, which he then modified to fit his classroom practice:

> I myself have been searching for curriculum that's already kind of NGSS-aligned because I don't want to redo my curriculum to fit into NGSS. I started to do that, but it was too much work. So, I'm implementing curriculum that's already NGSS-aligned. My Bio curriculum I found...I was randomly searching the Internet and I found this curriculum called [curriculum name]. And I found this curriculum online, read through, really liked it and started using it in my classroom. [Chemistry] I found that online too. That was created through [name of school district] science teachers there.

Similarly, Brian also knew about the district resources, but had chosen not to use them. Instead, Brian had been working with another colleague in his department and they were writing and implementing their own curriculum:

> We got together and spent some time in the summer writing curriculum, and we got, basically, about a third of the year worked out at that point. And then we always kept about a month ahead of ourselves. We continued to try stuff and kept notes on ourselves about, "Hey, this worked out well, this didn't work out so well." So I'm hoping that this year is going to be a refining kind of year.

Stephanie's school site had just purchased a curriculum package that had been developed by an outside organization. The school site was going to implement the new curriculum with the incoming 9th grade students in biology and within three to four years it was expected to be implemented in all the science courses:

> [Students] will be required take a [name of the curriculum] specific science course their freshman, sophomore, and junior year and then hopefully they'll take physics their fourth year. [Name of the curriculum] is pretty specific about what they want prescribed.

In general, teacher interview comments from the Lincoln high school district did not directly specify the absence of a district adopted science curriculum was a barrier to implementing the NGSS. However, teachers' comments pointed to two concerns related to curriculum: (1) what structures were put in place to ensure all science teachers were implementing curriculum aligned to the NGSS; and (2) was the autonomous implementation practice creating an inaccurate understanding and inconsistent implementation of the NGSS? These questions warrant further investigation.

Lastly, the lack of permanent and consumable supplies was another concern for teachers relative to implementing the NGSS. For example, Gabe commented on the lack of consumable supplies in his department:

> I think what they really need to do a better job though is on buying the consumables. So you got all your hardware so to speak, you got your lab ware and what not, you got your gas stove, probes and what not right? But there's consumables that need to be put in all that stuff so I really think there needs to be more resources towards consumables, which I think is kind of got pushed to the side because in reality the budget only really covers the photocopies.

Stephanie and Sonia had similar concerns about the shortage of equipment and supplies in their department, including lack of basic classroom supplies. Stephanie stated:

> Where we are going to be lacking is the support of the extra lab supplies. It's just really minimal in terms of the supplies…we need equipment. Also, my kids come to school with no paper, no pencils. We're always scrounging for paper towels and Kleenex. I bring Kleenex from home.

Sonia expressed similar concerns:

> I've got calculators and rulers because those don't walk away, but highlighters, pencils, pens, paper because not everything can be done on the computer. They need to have that hands-on experience. We don't have new hotplates. We don't have new electronic balances. We don't have those big-ticket items that would really make an impact on the way we teach, and so we're scrambling for who's got what. Who has the three balances? Who has the three digital balances that work? Hello?

Several of the teachers also felt the shortage of supplies was related to the lack of funding science departments received from their school sites. Amy, Glenn, and Stephanie all commented about the small amount of funding their science departments received each year. Glenn stated:

> [Funding] is small. For the whole Science department, it's like $500, $600, $800 bucks or something like that. We always get the number and go, "Really, that's it?" Having the funding to get everything that we need is going to be an issue.

Stephanie also mentioned her concern about the lack of funding, "We only have $2,000 for all our science classes. That's not enough." Amy who used to teach agricultural sciences where they had a larger budged commented on the fact that she was surprised how little funding science departments received:

> Teaching agriculture, we had funds to do stuff, and so it made it a lot easier, but teaching science...there's a lot less funds available. I think that might end up being tricky.

As a new teacher Bianca described the mixed messages she received about funding:

> My first year I think I got lucky in that I was able to order, I was actively encouraged by our principle to order whatever it was that I needed. And I did. I think that depleted our funds. That's the information I got my second year when I tried to ask for things. The department chair told me that I used all of the department funds the previous year so I could not order any other items.

Consequently, Bianca sought outside funding so she could continue to implement NGSS aligned activities in her classroom:

> Since then all materials that I've used in my classroom I've either bought with my own money or I've applied for the materials grant through my fellowship. So I've been able to take advantage of those at any time I need stuff for my classroom, where I want to try out an NGSS activity, which I can name off lots of them that I've been able to try out thanks to the fellowship. So I apply for those grants, and I get my solar cars, or duct tape, or whatever it is that I need that I want to try out in my classroom, and they support that.

Overall, survey responses and interview data supported the idea that teachers were anxious about the availability of resources they believed necessary for the implementation of the NGSS. While not all teachers agreed, the most common resources teachers described needing included curriculum, textbooks, equipment, and adequate science funding.

Chapter Summary

This study centered on the perceptions and experiences of 37 high school science teachers in two different high school districts in San Diego County. Based on survey and interview responses, findings from this study suggested that teachers were starting to develop some common language and understanding around the NGSS. Moreover, teachers had some understanding and knowledge of the instructional practices associated with the NGSS, which in turn was initiating changes in classroom practice. But, teachers were less confident about their skills and knowledge relative to science and engineering practices and how to use the NGSS performance expectations to assess student learning. Additional findings also suggested that teacher beliefs, emotions, networks, and school contextual factors were influencing how teachers were making sense of the NGSS.

Chapter 5: Discussion

This chapter includes a review of the study problem, the theoretical framework, and the methodology. In addition, this chapter offers a discussion of findings and suggestions for practice and future research.

Overview of the Problem

Teacher knowledge, beliefs, practices, professional learning opportunities, and school environment are important for understanding and improving educational processes. Not only are these factors closely related to a teacher's ability to shape a student's learning environment and influence student motivation and achievement, but they can also influence educational polices, such as changes to educational standards and practices (Coburn, 2001; Spillane et al., 2006). As a result, implementing new standards in the K-12 education system is not simply a matter of translating the accompanying ideas and curriculum into new practices in the classroom (Kelchtermans, 2005; Van Driel et al., 2001). Rather, these changes have to first be filtered through a teacher's preexisting belief structure and sensemaking processes; making the relationship between policy decisions and their actual implementation in schools and teacher practices a complicated process (Coburn, 2001, 2005a; Hargreaves, Liberman, Fullan, & Hopkins, 2009; Spillane et al., 2002; van den Berg, 2002). For these reasons, and given that the NGSS emphasizes a deeper understanding of scientific and engineering practices, a systematic and targeted approach for teacher support during the implementation of NGSS will be needed at all levels in the education system.

This study sought to examine how school leaders, professional development providers, district curricular staff, and instructional coaches could better support teachers during this time of change by examining (1) teacher beliefs and understandings of the NGSS; (2) how teachers are learning about the NGSS; (3) instructional shifts that are already occurring in the classroom and areas that may need additional support; and (4) factors teachers consider critical to the implementation process.

Review of Theoretical Framework

The theoretical framework for this research was based on sensemaking, which takes a cognitive approach to reform implementation. Research on sensemaking and policy interpretation suggests that individual implementers, such as teachers, must make sense of the explanations proposed by a new reform policy as well as the definitions of the problem implied by that policy (Spillane, 1998, 2000; Weick, 1995; Yanow, 1996). This work further suggested that sensemaking is situated, not only in organizational context, but also in the prior experiences and understandings of the individuals involved in the interpretation and implementation of a particular policy (Yanow, 1996). Therefore, an individual's understanding of both the problems and solutions of a new policy are framed by who they are as well as by prior experiences and the cultural, organizational, and structural contexts in which they are situated (Drake, 2002).

Related to education, sensemaking theory examines teacher prior knowledge and experiences and how they shape, prioritize, and interpret policy messages (Coburn, 2001; Park & Datnow, 2009; Spillane et al., 2002; Weick et al., 2005). As such, teachers' experiences, attitudes, beliefs, and knowledge can enable or constrain their understanding and enactment of the NGSS in their own classrooms (Banilower et al., 2013). Yet teacher cognitive structures are not static (Fullan, 2007). In fact, they are dynamic, mental structures that can change according to experience and knowledge, thereby forming the foundation of enduring curricular reform (Fullan, 2007). Therefore, this study used sensemaking theory as a guide in exploring the intersection of teacher knowledge, beliefs, and interpretations of NGSS in an effort to gain a better understanding of how teachers are constructing students' learning experiences in congruence with a new reform policy and/or how teachers themselves learn new ways of teaching. While research does exist on the process of teacher sensemaking in elementary and secondary schools relative to policy implementation, currently there is very little research on teacher sensemaking and the NGSS.

Review of Methodology

With teacher sensemaking supporting the methodology, this study used a mixed-methods design, which is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative data during research to understand a research problem more completely (Creswell, 2012; Tashakkori & Teddlie, 1998). This mixed-methods design allowed the researcher to capture both quantitative data and rich qualitative descriptions that would not have otherwise been available by using one approach. Moreover, when used in combination, quantitative and qualitative methods complement each other and provide a more complete picture of the research problem (Creswell & Plano Clark, 2011; Greene et al., 1989; Tashakori & Teddlie, 2010).

The first phase of the research design utilized a survey that included both closed and open-ended questions to capture qualitative and quantitative data about teacher knowledge, beliefs, instructional practices, professional development opportunities, and the school environment. The survey was administered utilizing a cross-sectional survey design. In a cross-sectional survey design, data is collected from a subgroup of the overall population in order to assess current attitudes, beliefs, opinions, or practices of other population members, in this case secondary science teachers (Creswell, 2012).

The second phase of the research design entailed semi-structured interviews focused on teacher knowledge, experiences, professional development, classroom practices, and school environment. The interview portion of the study was important because it provided a more in-depth look into how teachers are translating the NGSS into practice. The voices of the participants also provided a richer context to better explore teacher perceptions, implementation challenges, and the types of resources teachers are employing.

An integration of the quantitative and qualitative data collected took place as the final phase in the analysis. All patterns and findings from both phases of the study were connected and compared via the lens of the current literature, in order to examine the common themes in the quantitative and qualitative methodologies (Creswell & Plano Clark, 2011). The goal of integrating the data, as well as pursuing a mixed methods approach, was to provide the most in-depth understanding of the research questions and to add value and strength to the findings (Creswell & Plano Clark, 2011).

Summary of Findings

How teachers make sense of and implement a reform policy, such as the NGSS, depends upon the interaction of a teacher's cognitive structures, social context, and how the reform message has been represented (Spillane et al., 2002; Yanow, 1996). The following paragraphs show how the findings from this study related to the literature review, theoretical framework, and the problem of practice.

Studies examining teacher responses to reform efforts stress the importance of teacher knowledge. This includes teachers knowing which content ideas build on each other and what prior conceptions students might bring to the classroom (Shulman, 1987). Findings from this study suggested teachers were starting to develop some common language and understanding around the NGSS, which was resulting in small changes in classroom practice. Nonetheless, some teachers reported feeling less confident about their skills and knowledge relative to engineering practices. These findings were consistent with the literature. Bybee (2014) argued that teachers in the K-12 setting lack an understanding of engineering practices and do not understand the differences between scientific practices and engineering design. This opinion was reinforced in a study by Haag and Megowan (2015), in which teachers expressed concerns about their lack of an engineering background and the need for more training to better understand engineering in the context of science as intended by NGSS. However, even though these findings were expected, they are not without consequence due to the connection between teacher knowledge and instructional practices. Rather, studies that have investigated teacher knowledge and the degree to which a new reform policy will be implemented in the classroom have found that teacher knowledge and confidence levels often predict what subject matter content gets implemented in the classroom (Czerniak & Lumpe, 1996). As a result, if teachers do not feel knowledgeable or confident about implementing the NGSS practices in their classrooms, then the standards most likely will not get implemented.

Relatedly, teachers indicated they were familiar with the NGSS performance expectations (PEs), many stated they were still unclear about how to actually assess student learning using this new methodology. Bybee (2014) pointed out that teachers are going to be concerned about student assessments, particularly since assessments, as accountability measures, have become such a dominant force in K-12 education. Therefore, the first challenge for classroom teachers will be in translating these performance expectations into an instructional sequence that will provide adequate opportunities for students to learn the content of the standard (Krajcik et al., 2014). The second challenge will be in developing tasks that measure student progress toward mastery of the skills and content (Bybee, 2014). The last challenge, as teachers already mentioned in this study, will involve developing some new system to monitor and assign student grades (National Research Council, 2015). Meaning, implementing the NGSS will require assessments and grading practices that currently have not been developed. Therefore, it will be important for educational leaders to remember that this process will not only take time, but will require resources for professional training specific to assessment strategies so teachers can be properly prepared (National Research Council, 2015).

Additional findings also suggest that internal factors such as teacher beliefs and emotions were influencing how teachers were making sense of the NGSS. Studies on sensemaking in education have suggested that internal factors could influence how a teacher makes sense of a new reform policy. A teacher will often link the new policy message to their prior knowledge or belief systems, then frame and reframe messages until they arrive at a new understanding, a process Spillane and Callahan (1999) refer to as the “zone of enactment” (p. 144). Related to this study, teacher beliefs and emotions about the NGSS could potentially cause a teacher to pursue a different course of action than their peers (Coburn, 2001; Spillane & Zeuli, 1999). Therefore, to support teachers during the implementation of the NGSS, Schmidt and Datnow (2005) stated teacher beliefs and their emotional experience should be acknowledged and validated by school leaders as a natural part of the process. Additionally, in an effort to support teachers, school leaders will need to make sure that teachers are knowledgeable about the reform, have the tools to implement reform in their classrooms, and understand how the reform differs from their current practice (Schmidt & Datnow, 2005).

External factors such as collaboration, curricular resources, department funds, and administrative support were also influencing how teachers were making sense of the NGSS. However, access to regular engagement with other teachers in formal or informal structures appeared to have the strongest influence. This finding was consistent with the general literature which also suggests that teachers who routinely collaborate are better able to access and make use of the individual and collective resources embedded in their networks (Coburn, 2001). Applied to this study, in order for the NGSS to be effectively implemented in classrooms, teachers will need consistent access to effective collaborative structures.

Implications

School districts need to provide ongoing and high-quality professional development. Findings from this study suggested that teachers need additional training related to engineering practices and performance expectations. However, the traditional, fragmented professional development will be ineffective to meet the demands of the NGSS (Loucks-Horsley et al., 2010). Instead, teachers will need a new model of professional development, which includes activities that are engaging, collaborative, connected to classroom practice, and promote sustained learning (Penuel, Harris, & DeBarger, 2015). Consequently, professional learning opportunities should be designed so that teachers have a chance to grapple with both the science itself and how students think and learn about science (National Research Council, 2015). However, it is important to remember that it takes three to five years for teachers to fully implement a new program or practice (Loucks-Horsley et al., 2010). Thus, teachers will need ongoing professional development spread out over many years as they continuously refine their practice.

School districts need to provide high-quality curriculum materials and funding for classroom resources to help teachers meet the goals of the NGSS. Curriculum is widely viewed as an essential resource to help teachers understand new standards and support standards-based instruction (Allen & Penuel, 2014). However, since no single set of curriculum materials today is aligned to the NGSS, school districts will need to develop new resource materials, instructional units, and comprehensive curriculum based on the Framework and the NGSS (National Research

Council, 2015). Without a comprehensive curriculum, teachers may use curriculum resources from multiple resources, as was seen in this study, to design their own instruction that may or may not align to the NGSS. Additionally, without the proper curriculum supports teachers may find it difficult to implement instructional strategies that promote student engagement in science practices on a consistent basis (Allen & Penuel, 2014). Along with curriculum materials, teachers will need sufficient resources for students to actually do science. However, funding for adequate resources such as equipment and consumable supplies are often an issue for science teachers and not always accessible to all students in all schools (Haag & Megowan, 2015; Johnson, 2006, 2007; National Research Council, 2015). Yet research in science education has found that teachers often interpret new policies in relation to the availability of resources (Johnson, 2006, 2007b). Consequently, school districts and school sites will need to address these concerns and provide adequate funding if they want the NGSS to be faithfully implemented.

Based on the literature and responses in this study, schools and districts need to provide time for teachers to collaborate with others to increase teacher learning and change in practice. In the context of this study, teachers who routinely sought and utilized formal and informal networks not only increased their own understanding of the NGSS, but also started making changes in their instructional practice. This finding was supported by earlier studies, which have shown that collaborative structures can influence collective understanding of external initiatives (Coburn, 2001; Honig & Hatch, 2004; Spillane et al., 2002) as well as teaching practice (Coburn, 2001) and organizational learning (Bryk et al., 1999). Coburn and Russell (2008) also stated that teacher collaboration is important for policy implementation because it provides “opportunities for social capital transactions, access to information and expertise to support learning, and [the chance to] foster the depth of interaction that may be necessary for teachers to grapple with new approaches in ways that help them to question their assumptions and reconfigure their instructional practice over time" (p. 223). However, for many teachers the only collaborative networks they routinely access are school PLCs, which for some were viewed as ineffective. Therefore, it is imperative that principals and district administrators examine school and teacher characteristics that support or constrain teacher collaboration, especially within organized PLCs (Moolenaar, 2012).

Teachers need school site principals to understand the nature of changes to science education that is required by the NGSS. School principals play a key role in developing and sustaining reform efforts. They help to secure funding for professional development, and classroom resources; they are often involved in the design and implementation of curriculum, instruction, and assessment practices; and they monitor the effectiveness of implementation practices (Louis, 1994; Spillane et al., 2002; Waters, Marzano, & McNulty, 2003). Principals are essential, too, for realizing the vision of science for all students by promoting strategies and identifying resources for equitable access to science learning opportunities and participation in science classrooms (Penuel et al., 2015). Thus, in order for the school site principal and district administrators to understand the needs of science teachers, administrators will need to engage in professional development so they can recognize what is and is not aligned to the NGSS (Brunsell, Kneser, & Niemi, 2014; National Research Council, 2015). Administrators will also need an opportunity to experience the type of science envisioned by the Framework and the NGSS and have a chance to discuss with others what this means in the context of their school and the science teachers within them (National Research Council, 2015). School administrators who do not take the time to learn and understand the NGSS, will not only run the risk of placing unrealistic demands on teachers, but also undermining the entire implementation process.

Finally, there is a need for large-scale research about teacher perspectives on the NGSS for science. Such studies should focus on problems of practice such as teacher effectiveness, teacher beliefs about student learning, support from school districts, collaboration and teamwork among teachers, expert teachers, and coaching from master teachers. By researching different aspects of the school practices that contribute to the effective implementation of the NGSS, researchers could identify specific components that contribute to teacher beliefs about reform policies and what specific areas schools should concentrate on to effectively implement and sustain classroom practices aligned to the NGSS.

Limitations

In this section, the limitations at the end of Chapter Three are revisited, along with any new limitations that arose while the study was being conducted. This allowed for reflection on the research process and an acknowledgement of its limitations.

A limitation of the current study was that the findings provide a summary of high school teacher's perspectives about their early experiences with NGSS rather than a look how they enacted the standards in practice. As noted earlier, most school districts in California have just begun the process of implementing the NGSS. Consequently, teachers are still grappling with multiple contextual factors, such as how to teach the standards, the key instructional shifts they need to make, and how to access NGSS-aligned instructional materials. This limitation suggests a need for future studies to explore how the NGSS are enacted in practice. Such research, which may include classroom observations and examination of teachers' curriculum documents and instructional materials (e.g., textbooks, supplementary materials, and technologies), will provide important information about how the NGSS are impacting the teaching of science in classrooms.

Another limitation to the study was related to omissions in the survey design. The survey used in phase one consisted of 100 items (see Appendix L for survey questions) that measured teacher knowledge, beliefs, instructional practices, school resources, and professional development participation. The survey was designed to take approximately 15-25 minutes to complete. The development of the survey was based on the research questions, sensemaking theoretical framework, and the review of existing literature. While every precaution was made to ensure the validity of the survey, after the survey was administered some errors were detected. First, in Sections C through G (items 24-60), teachers responded to statements about their beliefs around science teaching including teacher effectiveness, confidence, motivation, and success in relation to the NGSS' vision of teaching and learning, but respondents commented in the open-ended survey question for this section that the questions were confusing and unclear. Second, in section J (items 84-97), teachers were asked to check all the different types of professional development they had attended the last year. Due to a survey design flaw, respondents were only able to select one answer. Several teachers did write in additional answers in the open-ended survey question for this section, which allowed the researcher to capture additional data that would have otherwise been lost. Lastly, the researcher made the decision not to pilot the study prior to data collection because the survey was generated from survey questions used in previous published studies. However, by making this decision the researcher lost valuable insight regarding survey length, survey design, question clarity, and sample data.

This investigation was also limited in scope and context because it only examined the experiences of a small sample of participants gathered from two school districts. While it was the study's goal to recruit a wide range of participants including teachers with diverse backgrounds, teaching experience, and content specialties, in reality the sample population tended to be more homogenous in nature. For instance, the majority of the participants were white female biology teachers with over 10 years of experience from the Lincoln Union High School District. Moreover, most of the respondents were teacher leaders from their own school sites or within the district, people who are more likely to respond to a survey in the first place. As a result, if this study was to be replicated the results cannot be generalized because responses and experiences recorded were unique to those teachers and their corresponding schools.

Lastly, my position as a school administrator in the Hidden Valley Union High School District may have limited teacher responses during the individual interviews. Before my current position as a school site administrator in the Hidden Valley Union High School District, I was a science teacher in the Lincoln Union High School District for several years. As a result, individuals who participated in the study from Lincoln may have viewed me differently than teachers from the Hidden Valley school district. This may be why more teachers participated in the study from Lincoln Union High School District than the Hidden Valley Union High School District. As a result, science teachers within in my district who were solicited to participate may have experienced the following emotions: fear, anxiety, distrust, and stress. Additionally, individuals who did participate in the study might have felt reluctant to voice their concerns or opinions, or their responses might have been based on what they thought I wanted to hear. Every attempt was made to minimize my position in the district. The following parameters were incorporated: I did not solicit participation at my own school site, participants were contacted using my personal university email account, the study was not discussed in the work setting, all correspondence iterated how confidentiality was being maintained, interviews were not conducted off-site to instill a sense of neutrality, and during the interviews all conversation was related to the study. Yet, despite these parameters, the authenticity of the teacher voices may have been reduced.

Appendix A
Science & Engineering Practices

Table A1: Science & Engineering Practices

Practices	Practice within Science	Practice within Engineering
Asking questions (for science) and defining problems (for engineering)	A basic practice of the scientist is the ability to formulate empirically answerable questions about phenomena to establish what is already know, and to determine what questions have yet to be satisfactorily answered.	Engineering begins with a problem that needs to be solved, such as "How can we reduce the nation's dependence on fossil fuels?" or "What can be done to reduce a particular disease?" or "How can we improve the fuel efficiency of automobiles?"
Developing and using models	Science often involves the construction and use of models and simulations to help develop explanations about natural phenomena.	Engineering makes use of models and simulations to analyze systems to identify flaw that might occur or to test possible solutions to a new problem.
Planning and carrying out investigations	A major practice of scientists is planning and carrying out systematic scientific investigations that require identifying variables and clarifying what counts as data.	Engineering investigations are conducted to gain data essential for specifying criteria or parameters and to test proposed designs.
Analyzing and interpreting data	Scientific investigations produce data that must be analyzed to derive meaning. Scientists use a range of tools to identify significant features & patterns in the data.	Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria.
Using mathematics and computational thinking	In science, mathematics and computation are fundamental tools for representing physical variables and their relationships.	In engineering, mathematical and computational representations of established relationships

		and principles are an integral part of the design process.
Constructing explanations (for science) and designing solutions (for engineering)	The goal of science is the construction of theories that provide explanatory accounts of the material world.	The goal of engineering design is a systematic approach to solving engineering problems that is based on scientific knowledge and models of the material world.
Engaging in argument from evidence	In science, reasoning and argument are essential for clarifying strengths and weaknesses of a line of evidence and for identifying the best explanation for a natural phenomenon.	In engineering, reasoning and arguments are essential for finding the best solution to a problem. Engineers collaborate with their peers throughout the design process.
Obtaining, evaluating, and communicating information	Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or learn about the findings of others.	Engineering cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively.

Note: Adapted from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012).

Appendix B
Performance Expectation for a High School Life Science Course

HS-LS1 From Molecules to Organisms: Structures and Processes

HS-LS1 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]

HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. [Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]

HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]

HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]

HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]

HS-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]

HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2)
- Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-4),(HS-LS1-5),(HS-LS1-7)

Planning and Carrying Out Investigations
Planning and carrying out in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-3)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1)
- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6)

Disciplinary Core Ideas

LS1.A: Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1) *(Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.)*
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2)
- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3)

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6)
- As matter and energy flow through different

Crosscutting Concepts

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-2), (HS-LS1-4)

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6)
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-7)

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-1)

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Appendix C
Introductory Email to School Districts

Dear______________________________,

I am a student in the Joint Doctoral Program (JDP) in Educational Leadership at University of California San Diego and California State University San Marcos. I am conducting research concerning secondary science teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS). My hope is that this research will provide school leaders, instructional coaches, and teacher mentors an understanding of the types of supports, professional development, aligned curriculum and materials needed to support science teachers in this transitional stage.

You are being contacted because I need permission to conduct this study in your district. The University of California San Diego Institutional Review Board (IRB) approved this study and its procedures and the study involves no foreseeable risks or harm to the respondents. I have attached the IRB for your review.

Once the study is approved I will contact your science teachers via email requesting their participation and a follow-up email with the actual survey link. The survey is about teachers' knowledge, beliefs, and professional development related to NGSS.

District and teacher confidentiality will be respected throughout this process. Pseudonyms for educational institutions will be used to minimize the risk of identification and responses will not be linked to any names or personal information.

I hope you will agree to allow me to conduct this research in your district. Feel free to contact me should you have any questions or concerns and thank you for your time and consideration.

Sincerely,
Christina Wilde
Doctoral Student
UCSD & CSUSM
wilde011@cougars.csusm.edu

Appendix D
Initial Email Invitation to Participate in Survey

Dear (NAME),

I am a student in the Joint Doctoral Program (JDP) in Educational Leadership at University of California San Diego and California State University San Marcos. I am conducting research concerning secondary science teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS). My hope is that this research will provide school leaders, instructional coaches, and teacher mentors an understanding of the types of supports, professional development, aligned curriculum and materials needed to support science teachers in this transitional stage.

You are being contacted because you are a science teacher at one of the two sites selected for this study. In one week you will be sent another email with a link to a survey. The survey is about your current knowledge, beliefs, and professional development related to NGSS. The survey will take approximately 15-25 minutes and can be completed electronically. Should you prefer to take the survey on paper, you can contact me directly for this option.

Your confidentiality will be respected throughout this process. Pseudonyms for educational institutions and teachers will be used to minimize the risk of identification. All email addresses, contact lists, and correspondence with participants will be kept confidential. All survey participants' names will be anonymized and kept confidential both during and after this study. The PI will STRIVE TO MAINTAIN confidentiality BY MAINTAINING AND STORING ALL SURVEY DATA in a UCSD Qualtrics account, created solely for the purpose of this research study. I hope you will participate in this research project. At this time no response is needed, but please feel free to contact me should you have any questions or concerns. Thank you in advance for your participation.

Sincerely,
Christina Wilde
Doctoral Student
UCSD & CSUSM
wilde011@cougars.csusm.edu

Appendix E
Individual Interview Participation Email Request

Dear (NAME),

Thank you for your participation in my survey. Your support of my research concerning secondary science teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS) is invaluable. In order to have a deeper understanding about teacher early experiences with NGSS, as well as to assist school leaders in better understanding the types of supports science teachers need in this transitional stage, I would like to invite you to participate in an individual interview.

You have been asked to participate in this study because you currently are a high school science teacher in one of the two high school districts participating in this study, you completed the survey, you indicated on the survey that you would be willing to participate in an individual interview, and you meet one of the following criteria: (a) your survey results indicate that you are an individual that feels highly prepared to implement the NGSS, or (b) your survey results indicate that you are an individual that feels under-prepared to implement the NGSS. A maximum of 10 individuals who meet these parameters will be asked to participate in the interview portion of the study. Please read this form carefully and ask any questions you may have before agreeing to be interviewed.

If you agree to participate in the individual interview process, you will be asked to meet with me for a 45-60-minute interview. This interview will include questions related to your thoughts, feelings, knowledge, and your preparedness to implement NGSS practices in your classroom. During this interview you will also have a chance to share about supports that you find helpful as well as any barriers related to NGSS implementation. This interview can take place on or off your school site, with the time and date to be determined based on your availability. With your permission, the interview will be audio taped and transcribed.

Your confidentiality will be respected throughout this process. The researcher will create a pseudonym name for each interview participant. The list of the actual participant's name and their pseudonym will be secured on a personal password-protected laptop. Only the researcher and faculty advisor overseeing the study will have access to this list. All written forms of data from the interviews (hand written notes, transcripts, data codes) will be scanned and/or saved on the same personal password-protected laptop and then the hardcopies will be appropriately destroyed. All data analysis will also be stored on the same personal password-protected laptop. You will be given the opportunity to review the transcribed interview and eliminate any comments or references you feel may be identifiable or have negative connotations. Research records will be kept confidential to the extent allowed by law. The UCSD Institutional Review Board may review research records.

Please respond back to this email letting me know if you are interested in participating in the individual interview portion of my study. I hope to begin interviews for the study before the end of the school year, so I welcome your response to this letter by June 1, 2017. If you have other questions or research-related problems, you may reach me at (760) 310-5834 or wilde011@cougars.csusm.edu. You may also call the Human Research Protections Program Office at 858-246-HRPP (858-246-4777) to inquire about your rights as a research subject or to report research-related problems.

I hope you will agree to participate and thank you again for your participation thus far in my research study.

Sincerely,
Christina Wilde
Doctoral Student
UCSD & CSUSM
wilde011@cougars.csusm.edu

Appendix F
Email Invitation to Participate in Survey

Dear (NAME),

You were contacted one week ago about participation in my research. I am a student in the Joint Doctoral Program (JDP) in Educational Leadership at University of California San Diego and California State University San Marcos. I am conducting research concerning secondary science teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS). My hope is that this research will provide school leaders, instructional coaches, and teacher mentors an understanding of the types of supports, professional development, aligned curriculum and materials needed to support science teachers in this transitional stage. You are being contacted again because you are a science teacher at one of the two sites selected for this study.

Below is the link to the survey. The survey is about your current knowledge, beliefs, and professional development related to NGSS. The survey will take approximately 15-25 minutes to complete and can be completed electronically. Should you prefer to take the survey on paper, you can contact me directly for this option.

(Qualtrics Survey Link)

Your confidentiality will be respected throughout this process. Pseudonyms for educational institutions and teachers will be used to minimize the risk of identification. All email addresses, contact lists, and correspondence with participants will be kept confidential. All survey participants' names will be anonymized and kept confidential both during and after this study. The PI will STRIVE TO MAINTAIN confidentiality BY MAINTAINING AND STORING ALL SURVEY DATA in a UCSD Qualtrics account, created solely for the purpose of this research stud. Before you begin the survey, you will see a consent page. By moving forward with the survey you are agreeing to participation and approving your consent. You may stop the survey at any time, with no penalties or consequences. Feel free to contact me should you have any questions or concerns and thank you in advance for your participation.

Sincerely,
Christina Wilde
Doctoral Student
UCSD & CSUSM
wilde011@cougars.csusm.edu

Appendix G
Reminder Email for Survey Participation

Dear (NAME),

This is a reminder and request for your participation in my research study. I am a student in the Joint Doctoral Program (JDP) in Educational Leadership at University of California San Diego and California State University San Marcos. I am conducting research concerning secondary science teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS). My hope is that this research will provide school leaders, instructional coaches, and teacher mentors an understanding of the types of supports, professional development, aligned curriculum and materials needed to support science teachers in this transitional stage. You are being contacted again because you are a science teacher at one of the two districts participating in this study.

Below is the link to the survey. The survey is about your current knowledge, beliefs, and professional development related to NGSS. The survey will take approximately 15-25 minutes and can be completed electronically. Should you prefer to take the survey on paper, you can contact me directly for this option.

(Qualtrics Survey Link)

Your confidentiality will be respected throughout this process. Before you begin the survey, you will see a consent page. Pseudonyms for educational institutions and teachers will be used to minimize the risk of identification. All email addresses, contact lists, and correspondence with participants will be kept confidential. All survey participants' names will be anonymized and kept confidential both during and after this study. The PI will STRIVE TO MAINTAIN confidentiality BY MAINTAINING AND STORING ALL SURVEY DATA in a UCSD Qualtrics account, created solely for the purpose of this research study. By moving forward with the survey you are agreeing to participation and approving your consent. You may stop the survey at any time, with no penalties or consequences.

Feel free to contact me should you have any questions or concerns and again, thank you in advance for your participation.

Sincerely,
Christina Wilde
Doctoral Student
UCSD & CSUSM
wilde011@cougars.csusm.edu

Appendix H
Final Email Reminder for Survey Participation

Dear (NAME),

This is a final reminder and request for your participation in my research study. I am a student in the Joint Doctoral Program (JDP) in Educational Leadership at University of California San Diego and California State University San Marcos. I am conducting research concerning secondary science teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS). My hope is that this research will provide school leaders, instructional coaches, and teacher mentors an understanding of the types of supports, professional development, aligned curriculum and materials needed to support science teachers in this transitional stage. You are being contacted again because you are a science teacher at one of the school districts participating in this study.

Below is the link to the survey. The survey is about your current knowledge, beliefs, and professional development related to NGSS. The survey will take approximately 15-25 minutes and can be completed electronically. Should you prefer to take the survey on paper, you can contact me directly for this option.

(Qualtrics Survey Link)

Your confidentiality will be respected throughout this process. Pseudonyms for educational institutions and teachers will be used to minimize the risk of identification. All email addresses, contact lists, and correspondence with participants will be kept confidential. All survey participants' names will be anonymized and kept confidential both during and after this study. The PI will STRIVE TO MAINTAIN confidentiality BY MAINTAINING AND STORING ALL SURVEY DATA in a UCSD Qualtrics account, created solely for the purpose of this research study. Before you begin the survey, you will see a consent page. By moving forward with the survey you are agreeing to participation and approving your consent. You may stop the survey at any time, with no penalties or consequences.

Feel free to contact me should you have any questions or concerns and again, thank you in advance for your participation.

Sincerely,
Christina Wilde
Doctoral Student
UCSD & CSUSM
wilde011@cougars.csusm.edu

Appendix I
Survey Consent Form

University of California San Diego
Consent to Act as a Research Subject

How Teachers are Making Sense of the Next Generation Science Standards in Secondary Schools: A Mixed-Methods Study

Who is conducting the study, why you have been asked to participate, how you were selected, and what is the approximate number of participants in the study?
Christina Wilde, a doctoral student is conducting a research study to find out more about teachers' perspectives pertaining to their early experiences with the Next Generation Science Standards (NGSS. You have been asked to participate in this study because you currently **are a science teacher in one of the two school districts participating in this study.** There will be approximately 125 participants in this study. Please read this form carefully and ask any questions you may have before agreeing to be in the study. You must be 18 or older to participate in the study.

Why is this study being done?
The purpose of this study is to assess teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS), as well to assist school leaders, instructional coaches, and teacher mentors in better understanding the types of supports, professional development, aligned curriculum and materials needed to support science teachers during this transitional stage.

What will happen to you in this study and which procedures are standard of care and which are experimental?
If you agree to be in this study, you will be asked to complete a brief survey about your understanding, motivation, beliefs, and teaching practices related to the Next Generation Science Standards.

How much time will each study procedure take, what is your total time commitment, and how long will the study last?
The survey should take approximately 15-25 minutes to complete.

What risks are associated with this study?
Participation in this study may involve some added risks or discomforts. These include the following:

A potential for the loss of confidentiality: While every effort is made to reduce risk, there exists a possibility of a loss of confidentiality in this study. However, safeguards have been put in place to minimize any risk to you. District and teacher confidentiality will be respected throughout this process. Pseudonyms for educational institutions and teachers will be used to minimize the risk of identification. All email addresses, contact lists, and correspondence with participants will be kept confidential and sent from a personal password- protected laptop. Correspondence with participants will be sent individually not as a group or listserv. All survey participants' names will be anonymized and kept confidential both during and after this study. The PI will STRIVE TO MAINTAIN confidentiality BY MAINTAINING AND STORING ALL SURVEY DATA in a UCSD Qualtrics account, created solely for the purpose of this research study. In the instance a participant requests a paper survey, the data will be scanned and saved on a personal password-protected laptop and the hard copy will be appropriately destroyed. At the end of the study, all electronic documents related to the research study will be organized and placed into a file on the password-protected laptop. After one year, the electronic file will be deleted. Research records will be kept confidential to the extent allowed by law. The UCSD Institutional Review Board may review research records.

A potential for emotional stress, boredom or fatigue: To minimize the impact of emotional stress, boredom, or fatigue, participants are under no obligation to complete the survey. Once started participants you may also stop the survey at any time. The survey can be completed from any personal electronic device of your choice and at any time of the day.

Under California law, we must report information about known or reasonably suspected incidents of abuse or neglect of a child, dependent adult or elder including physical, sexual, emotional, and financial abuse or neglect. If any investigator has or is given such information, he or she may be required to report such information to the appropriate authorities.

Because this is a research study, there may also be some unknown risks that are currently unforeseeable. You will be informed of any significant new findings

What are the alternatives to participating in this study?
The alternative to participate in this study is to not participate. You will not be penalized in any way for not agreeing to participate in this study.

What benefits can be reasonably expected?
There may or may not be any direct benefit to you from participating this study. The main benefit you may receive from participating in this study is the opportunity to provide feedback about your early experiences with the implementation of the Next Generation Science Standards The investigator, however, may learn more about (a) the characteristics of teachers who feel well prepared to implement NGSS, (b) perceived barriers for teachers' who feel underprepared, (c) areas of content and instructional challenges, and (d) professional development needs. Findings from this research then could be used to inform school leaders, practitioners, and policy makers about the type of supports, professional development, aligned curriculum, and materials that will be needed to support science teachers in this transitional stage, thus benefiting the field of education and society at large.

Can you choose to not participate or withdraw from the study without penalty or loss of benefits?
Participation in this study is entirely voluntary. You may refuse to participate or withdraw or refuse to answer specific questions on the survey at any time without penalty or loss of benefits to which you are entitled. If you decide that you no longer wish to continue in this study, you will be required to contact the researcher, Christina Wilde at (760) 310-5834 or email wilde011@cougars.csusm.edu.

You will be told if any important new information is found during the course of this study that may affect your wanting to continue.

Can you be withdrawn from the study without your consent?
The PI may remove you from the study without your consent if the PI feels it is in your best interest or the best interest of the study. You may also be withdrawn from the study if you do not follow the instructions given you by the study personnel.

Will you be compensated for participating in this study?
There is no compensation for your time and travel. As a participant you will be responsible for any transportation and parking costs, and such costs will not be reimbursed.

Are there any costs associated with participating in this study?
There will be no cost to you for participating in this study.

What if you are injured as a direct result of being in this study?
If you are injured as a direct result of participation in this research, the University of California will provide any medical care you need to treat those injuries. The University will not provide any other form of compensation to you if you are injured. You may call the Human Research Protections Program Office at 858-246-HRPP (858-246-4777) for more information about this, to inquire about your rights as a research subject or to report research-related problems.

Who can you call if you have questions?
Christina Wilde has explained this study to you and answered your questions. If you have other questions or research-related problems, you may reach Christina Wilde at (760) 310-5834 or email wilde011@cougars.csusm.edu.

You may call the Human Research Protections Program Office at 858-246-HRPP (858-246-4777) to inquire about your rights as a research subject or to report research-related problems.

By continuing on with the survey, you are verifying that you, as a participant, have read this consent information and voluntarily agree to participate in this study. You may print this page for your records. Thank you for your participation.

Appendix J
Interview Consent Form

University of California San Diego
Consent to Act as a Research Subject

How Teachers are Making Sense of the Next Generation Science Standards in Secondary Schools: A Mixed-Methods Study

Who is conducting the study, why you have been asked to participate, how you were selected, and what is the approximate number of participants in the study?
Christina Wilde, a doctoral student is conducting a research study to find out more about teachers' perspectives pertaining to their early experiences with the Next Generation Science Standards (NGSS). You have been asked to participate in this study because you currently are a high school science teacher in one of the two high school districts participating in this study, you completed the survey, you indicated on the survey that you would be willing to participate in an individual interview, and you meet one of the following criteria: (a) your survey results indicate that you are an individual that feels highly prepared to implement the NGSS, or (b) your survey results indicate that you are an individual that feels under-prepared to implement the NGSS. A maximum of 10 individuals who meet these parameters will be asked to participate in the interview portion of the study. Please read this form carefully and ask any questions you may have before agreeing to be interviewed. You must be 18 or older to participate in the study.

Why is this study being done?
The purpose of this study is to assess teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS), as well to assist school leaders, instructional coaches, and teacher mentors in better understanding the types of supports, professional development, aligned curriculum and materials needed to support science teachers during this transitional stage.

What will happen to you in this study and which procedures are standard of care and which are experimental?
If you agree to participate in the individual interview process, you will be asked to meet with me for a 30-minute interview. This interview will include questions related to your thoughts, feelings, knowledge, and your preparedness to implement NGSS practices in your classroom. During this interview you will also have a chance to share about supports that you find helpful as well as any barriers related to NGSS implementation. This interview can take place on or off your school site, with the time and date to be determined based on your availability.

How much time will each study procedure take, what is your total time commitment, and how long will the study last?
The interview will take approximately 30 minutes to complete.

What risks are associated with this study?
Participation in this study may involve some added risks or discomforts. These include the following:

A potential for the loss of confidentiality: While every effort is made to reduce risk, there exists a possibility of a loss of confidentiality in this study. However, safeguards have been put in place to minimize any risk to you. District and teacher confidentiality will be respected throughout this process. The researcher will create a pseudonym name for each interview participant. The list of the actual participant's name and their pseudonym will be secured on a personal password-protected laptop. Only the researcher and faculty advisor overseeing the study will have access to this list. All written forms of data from the interviews (hand written notes, transcripts, data codes) will be scanned and/or saved on the same personal password-protected laptop and then the hardcopies will be appropriately destroyed. All data analysis will also be stored on the same personal password-protected laptop. Research records will be kept confidential to the extent allowed by law. The UCSD Institutional Review Board may review research records.

A potential for emotional stress, boredom or fatigue: To minimize the impact of emotional stress, boredom, or fatigue, you are under no obligation to complete the interview. Once started you may also stop the interview at any time.

Under California law, we must report information about known or reasonably suspected incidents of abuse or neglect of a child, dependent adult or elder including physical, sexual, emotional, and financial abuse or neglect. If any investigator has or is given such information, he or she may be required to report such information to the appropriate authorities.

Because this is a research study, there may also be some unknown risks that are currently unforeseeable. You will be informed of any significant new findings.

What are the alternatives to participating in this study?
The alternative to participate in this study is to not participate. You will not be penalized in any way for not agreeing to participate in this study.

What benefits can be reasonably expected?
There may or may not be any direct benefit to you from participating this study. The main benefit you may receive from participating in this study is the opportunity to provide feedback about your early experiences with the implementation of the Next Generation Science Standards The investigator, however, may learn more about (a) the characteristics of teachers who feel well prepared to implement NGSS, (b) perceived barriers for teachers' who feel underprepared, (c) areas of content and instructional challenges, and (d) professional development needs. Findings from this research then could be used to inform school leaders, practitioners, and policy makers about the type of supports, professional development, aligned curriculum, and materials that will be needed to support science teachers in this transitional stage, thus benefiting the field of education and society at large.

Can you choose to not participate or withdraw from the study without penalty or loss of benefits?
Participation in research is entirely voluntary. You may refuse to participate or withdraw or refuse to answer specific questions in an interview or on a questionnaire at any time without penalty or loss of benefits to which you are entitled. If you decide that you no longer wish to continue in this study, you will be required to call Christina Wilde, the researcher at (760) 310-5834 or email wilde011@cougars.csusm.edu.

You will be told if any important new information is found during the course of this study that may affect your wanting to continue.

Can you be withdrawn from the study without your consent?
The PI may remove you from the study without your consent if the PI feels it is in your best interest or the best interest of the study. You may also be withdrawn from the study if you do not follow the instructions given you by the study personnel.

Will you be compensated for participating in this study?
There is no compensation for your time and travel. As a participant you will be responsible for any transportation and parking costs, and such costs will not be reimbursed.

Are there any costs associated with participating in this study?
There will be no cost to you for participating in this study.

What if you are injured as a direct result of being in this study?
If you are injured as a direct result of participation in this research, the University of California will provide any medical care you need to treat those injuries. The University will not provide any other form of compensation to you if you are injured. You may call the Human Research Protections Program Office at 858-246-HRPP (858-246-4777) for more information about this, to inquire about your rights as a research subject or to report research-related problems.

Who can you call if you have questions?
Christina Wilde has explained this study to you and answered your questions. If you have other questions or research-related problems, you may reach Christina Wilde at (760) 310-5834 or wilde011@cougars.csusm.edu.

You may call the Human Research Protections Program Office at 858-246-HRPP (858-246-4777) to inquire about your rights as a research subject or to report research-related problems.

Your Signature and Consent
You have received a copy of this consent document.

You agree to participate.

____ _______________
Subject's signature Date

Appendix K
Individual Interview Protocol and Questions

Interview Protocol- Individual semi-structured
Time of Interview:
Date:
Place:
Name of Interviewer:
Name of Participant (Pseudonym):
Name of School District (Pseudonym):

Introduction to the interview: The purpose of this study is to research secondary science teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS). My hope is that this research will provide school leaders, instructional coaches, and teacher mentors an understanding of the types of supports, professional development, aligned curriculum and materials needed to support science teachers in this transitional stage.

I have collected survey data and I am now interviewing individual science teachers to more deeply understand this topic and my proposed research questions. The location of this study and all participants' identities will be made anonymous in this interview, collection of data and the writing of the findings. All data collected will be stored in a password-protected computer, for use only by the researcher. All hard copies of any material from the interview will be scanned on the computer and then appropriately destroyed. The interview will take approximately 60 minutes.

[Provide an opportunity for the participant to re-read and ask any questions about the signed consent form]
[Turn on and test recording device]
[Begin questions]

Questions:

1. Tell me a little about your experience as a science teacher. What science subjects do you teach? How long have you been teaching? What other responsibilities do you have at school?
2. Describe a typical lesson in your classroom.
3. How would you describe your role as a science teacher? The role of the student?
4. What is your experience with the NGSS? What are your feelings about the NGSS?

5. As a result of the NGSS, what changes have you made in your classroom instruction, if any?
6. What supports or opportunities have been made available to at your school site/district to help you transition to the NGSS? What has been helpful? Not helpful?
7. How prepared do you feel to implement NGSS? What are some areas of concern? What areas do you feel more confident?
8. What impact do you think the NGSS will have on students that are not motivated? ELL students? Students with IEP's?
9. How do you currently support students that are not motivated? ELL students? Students with IEP's?
10. Is there anything else that you would like to add?

Appendix L
Survey Instrument

University of California San Diego
Consent to Act as a Research Subject

How Teachers are Making Sense of the Next Generation Science Standards in Secondary Schools: A Mixed-Methods Study

Who is conducting the study, why you have been asked to participate, how you were selected, and what is the approximate number of participants in the study?
Christina Wilde, a doctoral student is conducting a research study to find out more about teachers' perspectives pertaining to their early experiences with the Next Generation Science Standards (NGSS. You have been asked to participate in this study because you currently **are a science teacher in one of the two school districts participating in this study.** There will be approximately 125 participants in this study. Please read this form carefully and ask any questions you may have before agreeing to be in the study. You must be 18 or older to participate in the study.

Why is this study being done?
The purpose of this study is to assess teachers' perspectives about their early experiences with the Next Generation Science Standards (NGSS), as well to assist school leaders, instructional coaches, and teacher mentors in better understanding the types of supports, professional development, aligned curriculum and materials needed to support science teachers during this transitional stage.

What will happen to you in this study and which procedures are standard of care and which are experimental?
If you agree to be in this study, you will be asked to complete a brief survey about your understanding, motivation, beliefs, and teaching practices related to the Next Generation Science Standards.

How much time will each study procedure take, what is your total time commitment, and how long will the study last?
The survey should take approximately 15-25 minutes to complete.

What risks are associated with this study?
Participation in this study may involve some added risks or discomforts. These include the following:

A potential for the loss of confidentiality: While every effort is made to reduce risk, there exists a possibility of a loss of confidentiality in this study. However, safeguards have been put in place to minimize any risk to you. District and teacher confidentiality will be respected throughout this process. Pseudonyms for educational institutions and teachers will be used to minimize the risk of identification. All email addresses, contact lists, and correspondence with participants will be kept confidential and sent from a personal password- protected laptop. Correspondence with participants will be sent individually not as a group or listserv. All survey participants' names will be anonymized and kept confidential both during and after this study. The PI will STRIVE TO MAINTAIN confidentiality BY MAINTAINING AND STORING ALL SURVEY DATA in a UCSD Qualtrics account, created solely for the purpose of this research study. In the instance a participant requests a paper survey, the data will be scanned and saved on a personal password-protected laptop and the hard copy will be appropriately destroyed. At the end of the study, all electronic documents related to the research study will be organized and placed into a file on the password-protected laptop. After one year, the electronic file will be deleted. Research records will be kept confidential to the extent allowed by law. The UCSD Institutional Review Board may review research records.

A potential for emotional stress, boredom or fatigue: To minimize the impact of emotional stress, boredom, or fatigue, participants are under no obligation to complete the survey. Once started participants you may also stop the survey at any time. The survey can be completed from any personal electronic device of your choice and at any time of the day.

Under California law, we must report information about known or reasonably suspected incidents of abuse or neglect of a child, dependent adult or elder including physical, sexual, emotional, and financial abuse or neglect. If any investigator has or is given such information, he or she may be required to report such information to the appropriate authorities.

Because this is a research study, there may also be some unknown risks that are currently unforeseeable. You will be informed of any significant new findings

What are the alternatives to participating in this study?
The alternative to participate in this study is to not participate. You will not be penalized in any way for not agreeing to participate in this study.

What benefits can be reasonably expected?
There may or may not be any direct benefit to you from participating this study. The main benefit you may receive from participating in this study is the opportunity to provide feedback about your early experiences with the implementation of the Next Generation Science Standards The investigator, however, may learn more about (a) the characteristics of teachers who feel well prepared to implement NGSS, (b) perceived barriers for teachers' who feel underprepared, (c) areas of content and instructional challenges, and (d) professional development needs. Findings from this research then could be used to inform school leaders, practitioners, and policy makers about the type of supports, professional development, aligned curriculum, and materials that will be needed to support science teachers in this transitional stage, thus benefiting the field of education and society at large.

Can you choose to not participate or withdraw from the study without penalty or loss of benefits?
Participation in this study is entirely voluntary. You may refuse to participate or withdraw or refuse to answer specific questions on the survey at any time without penalty or loss of benefits to which you are entitled. If you decide that you no longer wish to continue in this study, you will be required to contact the researcher, Christina Wilde at (760) 310-5834 or email wilde011@cougars.csusm.edu.

You will be told if any important new information is found during the course of this study that may affect your wanting to continue.

Can you be withdrawn from the study without your consent?
The PI may remove you from the study without your consent if the PI feels it is in your best interest or the best interest of the study. You may also be withdrawn from the study if you do not follow the instructions given you by the study personnel.

Will you be compensated for participating in this study?
There is no compensation for your time and travel. As a participant you will be responsible for any transportation and parking costs, and such costs will not be reimbursed.

Are there any costs associated with participating in this study?
There will be no cost to you for participating in this study.

What if you are injured as a direct result of being in this study?
If you are injured as a direct result of participation in this research, the University of California will provide any medical care you need to treat those injuries. The University will not provide any other form of compensation to you if you are injured. You may call the Human Research Protections Program Office at 858-246-HRPP (858-246-4777) for more information about this, to inquire about your rights as a research subject or to report research-related problems.

Who can you call if you have questions?
Christina Wilde has explained this study to you and answered your questions. If you have other questions or research-related problems, you may reach Christina Wilde at (760) 310-5834 or email wilde011@cougars.csusm.edu.

You may call the Human Research Protections Program Office at 858-246-HRPP (858-246-4777) to inquire about your rights as a research subject or to report research-related problems.

By continuing on with the survey, you are verifying that you, as a participant, have read this consent information and voluntarily agree to participate in this study. You may print this page for your records. Thank you for your participation.

Q2 Gender:

- ❍ Male
- ❍ Female

Q3 Age (years):

- ❍ 20-25
- ❍ 26-30
- ❍ 31-35
- ❍ 36-40
- ❍ 41-45
- ❍ 46-50
- ❍ 51-55
- ❍ 56-60
- ❍ 61 or over

Q4 To which racial or ethnic group(s) do you most identify?

- ❍ American Indian/Native American
- ❍ Asian
- ❍ Black/African American
- ❍ Hispanic/Latino
- ❍ White/Caucasian
- ❍ Pacific Islander
- ❍ Other

Q5 Education: What is the highest degree or level of school you have completed? If currently enrolled, highest degree received.

- ❍ Bachelor's degree
- ❍ Master's Degree
- ❍ Doctorate degree
- ❍ Other please specify ____________________

Q6 What type of teacher certification program did you participate in?

- ❍ Certification was part of your undergraduate degree
- ❍ Certification was a post-baccalaureate degree program
- ❍ I am not currently certified to teach science

Q7 Teaching Experience (years):

- ❍ 0-5
- ❍ 6-10
- ❍ 11-15
- ❍ 16-20
- ❍ 21-25
- ❍ 26-30
- ❍ more than 30 years

Q8 List the Primary science subject you teach

Q9 If you teach another science subject regularly please list it here:

Q10 School district in which you work

Q12 Rate your understanding of the following changes to science education envisioned in the National Research Council's "Framework for K-12 Science Education" and carried forth in the Next Generation Science Standards (NGSS):

	Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
"All Standards, All Students"	❍	❍	❍	❍	❍
Engaging students in "Three Dimensional Learning"	❍	❍	❍	❍	❍
Science and Engineering Practices	❍	❍	❍	❍	❍
Disciplinary Core Ideas	❍	❍	❍	❍	❍
Crosscutting Concepts	❍	❍	❍	❍	❍
Performance Expectations	❍	❍	❍	❍	❍
Engineering Design	❍	❍	❍	❍	❍
Links among engineering, technology, science, & society	❍	❍	❍	❍	❍

Q13 Rate your understanding of the following elements of the NGSS:

	Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
Relationship among Performance Expectations, Foundations Boxes and Connections Boxes	❍	❍	❍	❍	❍
How the Performance Expectations relate to curriculum development	❍	❍	❍	❍	❍
How the Performance Expectations relate to assessment of student learning	❍	❍	❍	❍	❍
The alignment of NGSS and the Common Core State Standards (CCSS)	❍	❍	❍	❍	❍

Q14 Optional: Please share any comments or concerns you may have about your knowledge of the NGSS practices.

Q15 Please indicate the degree to which you agree or disagree with each statement below:

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
The inadequacy of a student's science background can be overcome by good teaching.	❍	❍	❍	❍	❍
The low science achievement of some students cannot generally be blamed on their teachers.	❍	❍	❍	❍	❍
When a low achieving student progresses in science, it is usually due to extra attention given by the teacher.	❍	❍	❍	❍	❍
The teacher is generally responsible for the achievement of students in science.	❍	❍	❍	❍	❍
Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	❍	❍	❍	❍	❍
Effectiveness in science teaching has little influence on the achievement of students with low motivation.	❍	❍	❍	❍	❍

Q16 Please indicate the degree to which you agree or disagree with each statement below:

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	❍	❍	❍	❍	❍
I am continually finding better ways to teach science.	❍	❍	❍	❍	❍
When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.	❍	❍	❍	❍	❍
I know the steps necessary to teach science concepts effectively.	❍	❍	❍	❍	❍
I am effective in monitoring science experiments.	❍	❍	❍	❍	❍
If students are underachieving in science, it is most likely due to ineffective science teaching.	❍	❍	❍	❍	❍

Q17 Please indicate the degree to which you agree with each statement below:

	Strongly agree	agree	Neither agree nor disagree	Disagree	Strongly disagree
I am typically able to answer students' science questions	❍	❍	❍	❍	❍
I am typically able to answer students engineering questions	❍	❍	❍	❍	❍
I am typically able to answer students' math questions	❍	❍	❍	❍	❍
I am typically anxious about my math skills	❍	❍	❍	❍	❍
I currently have the necessary skills to integrate science and engineering practices	❍	❍	❍	❍	❍
I am currently able to design and deliver science activities	❍	❍	❍	❍	❍
I am currently able to design and deliver engineering skills	❍	❍	❍	❍	❍

Q 18 Rate how motivated you are in performing the following tasks in your classroom:

	Highly motivated	Little above average motivation	Average motivation	Little below average motivation	No motivation
Asking questions that can be answered with data	❍	❍	❍	❍	❍
Developing and using models	❍	❍	❍	❍	❍
Helping students to plan and carry out rigorous scientific investigations (collect accurate data)	❍	❍	❍	❍	❍
Analyzing and interpreting data	❍	❍	❍	❍	❍
Using mathematics and technology to make sense of data	❍	❍	❍	❍	❍
Constructing explanations for science and designing solutions for engineering	❍	❍	❍	❍	❍
Engaging in argument from evidence	❍	❍	❍	❍	❍
Obtaining, evaluating, and communicating information	❍	❍	❍	❍	❍
Effectively using engineering problems to help students understand science concepts	❍	❍	❍	❍	❍

Q 19 Rate how certain you are about your success in performing the following tasks:

	Strong expectation of success	Above average expectation of success	Moderate expectation of success	Some expectation of success	Cannot expect success at all
Asking questions that can be answered with data.	❍	❍	❍	❍	❍
Helping students to plan and carry out rigorous scientific investigations (collect accurate data).	❍	❍	❍	❍	❍
Analyzing and interpreting data.	❍	❍	❍	❍	❍
Using mathematics and technology to make sense of data.	❍	❍	❍	❍	❍
Constructing explanations (for science) and designing solutions (for engineering).	❍	❍	❍	❍	❍
Engaging in argument from evidence.	❍	❍	❍	❍	❍
Obtaining, evaluating, and communicating information.	❍	❍	❍	❍	❍
Effectively using engineering (design and building) problems to help students understand science concepts.	❍	❍	❍	❍	❍

Q 20 Optional: Please share any comments or concerns you may have about your ability to implement the teaching and learning practices described in the NGSS.

Q 21 How often in your science classroom do you engage in the following:

	Daily or almost daily	Often (once or twice a week)	Sometimes (once or twice a month)	Rarely (a few times a year)	Never
Provide direct instruction to explain science concepts	❍	❍	❍	❍	❍
Demonstrate an experiment and have students watch	❍	❍	❍	❍	❍
Use activity sheets to reinforce skills or content	❍	❍	❍	❍	❍
Go over science vocabulary	❍	❍	❍	❍	❍
Apply science concepts to explain natural events or real-world situation	❍	❍	❍	❍	❍
Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	❍	❍	❍	❍	❍
Discuss students' prior knowledge or experience related to the science topic or concept	❍	❍	❍	❍	❍
Use open-ended questions to stimulate whole class discussion (most students participate)	❍	❍	❍	❍	❍
Have students work with each other in small groups	❍	❍	❍	❍	❍
Encourage students to explain concepts to one another	❍	❍	❍	❍	❍

Q 22 How often in your science classrooms do your students engage in the following:

	Daily or almost daily	Often (once or twice a week)	Sometimes (once or twice a month)	Rarely (a few times a year)	Never
Generate questions or predictions to explore scientific ideas or problems	❍	❍	❍	❍	❍
Identify questions from observations of phenomenon	❍	❍	❍	❍	❍
Design or implement their OWN investigations	❍	❍	❍	❍	❍
Make and record Observations	❍	❍	❍	❍	❍
Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	❍	❍	❍	❍	❍
Develop a conceptual model based on data or observations (model is not provided by textbook or teacher)	❍	❍	❍	❍	❍
Organize data into charts or graphs	❍	❍	❍	❍	❍
Analyze relationships using charts or graphs	❍	❍	❍	❍	❍
Explain the reasoning behind an idea	❍	❍	❍	❍	❍
Make an argument that supports or refutes a claim	❍	❍	❍	❍	❍
Present procedures, data and conclusions to the class (either informally or in formal presentation)	❍	❍	❍	❍	❍
Critically synthesize information from different sources (i.e., text or media)	❍	❍	❍	❍	❍

Q 23 Optional: Please share your comments or concerns about your current instructional practices and their alignment to the vision of the NGSS.

Q 24 School environment: In the first column please indicate the degree to which you believe each factor will enable you to effectively implement the NGSS:

	The following factors would enable me to effectively implement NGSS practices					How likely is it that these factors will be available to you during the next school year?				
	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree	Strongly agree	Agree	Undecided	Disagree e	Strongl y disagree
Professional development on NGSS practices	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Support from other teachers (coaching, informal discussions, etc.)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Planning time with other teachers	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Expendable science supplies (paper, chemicals, etc.)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Permanent science equipment (microscopes, glassware, etc.)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Technology (computers, software, Internet access, etc.)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Adoption of an official school science curriculum (goals, objectives, topics, etc.)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Adoption of official science curriculum materials (textbooks, lab manuals, activity books, etc.)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Support from administration	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Teacher input and decision making	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q25 Please share your comments or concerns about the availability of resources to help you effectively implement the NGSS practices in your classroom.

Q26 What is the total amount of time you have spent on professional development related to NGSS in the last 12 months? (Include attendance at professional meetings, workshops, and conferences, but do not include time you spent providing professional development for other teachers.)

- More than 35 hours
- 16-35 hours
- 6-15 hours
- Less than 6 hours
- None

Q27 In the last year have you participated in any of the following activities where learning about NGSS was the main focus? Please check all that apply:

- Attended a national or state science conference session
- Attended a workshop sponsored by your school district
- Attended a workshop that was sponsored by an agency other than your district
- Met informally with a group of teachers on a regular basis
- Professional Learning Community / Department meeting
- Worked with a science coach or mentor, part of a formal arrangement that is recognized or supported by the school or district.
- Paid planning time (in addition to prep period)
- Other ____________________
- None of the above

Q28 Optional: Please share any comments or concerns you may have about professional development opportunities related to NGSS

Q29 Optional: Please share any other comments or concerns you may have about NGSS that were not addressed previously.

Q30 If you would be willing to participate in a personal interview about your perceptions and experiences about the Next Generation Science Standards, please provide an email address at which you can be contacted in the textbox below. As with this survey, all interview participants' names will be anonymized and kept confidential both during and after this study.

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