HIGH SCHOOL SCIENCE TEACHERS' RECEPTIVITY TO THE
NEXT GENERATION SCIENCE STANDARDS:
AN EXAMINATION OF DISCIPLINE SPECIFIC FACTORS.

A doctoral thesis presented
by
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Abstract

The Next Generation Science Standards (NGSS), are the biggest change to American science education since the National Science Education Standards (NSES) were published. While inquiry was central to the NSES, science assessment largely addressed factual knowledge acquisition. The NGSS represent a significant practical change for teachers as they mark a return to the ideals specified in the National Science Education Standards (NSES) and Benchmarks for Science Literacy. The purpose of this explanatory sequential, mixed-methods study was to identify and compare the factors that influenced high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS. The survey data identified three factors as significant predictors of teacher receptivity: teachers’ non-monetary cost-benefit analysis, alignment between the NGSS and their current teaching style, and concerns about student readiness. To understand how these factors operate in the classroom, both receptive and non-receptive teachers were interviewed. In terms of cost-benefit analysis, all teachers agree that time is a significant cost. This includes the time it takes to adapt lessons to the NGSS, and the time it takes to teach in a way that integrates the three parts of the NGSS which are the practices of science and engineering, the crosscutting concepts, and the disciplinary core ideas. In terms of alignment between their teaching style and the NGSS, teachers talked about the lack of examples of what NGSS-aligned instruction looks like and the dearth of accessible high quality professional development. Finally, concerns about students’ readiness focused on both inadequate preparation for college-level science coursework and deficits in science instruction in the lower grades.

Keywords: Next Generation Science Standards; biology teachers; chemistry teachers; physics teachers; high school science; curriculum change; constructivist pedagogy.
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Dedication

For Amelia Myrna:
Never stop taking delight in searching for answers to the questions that excite you.
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Chapter 1: Introduction

**Problem Statement**

The sweeping changes brought about by the No Child Left Behind Act of 2002 (NCLB) produced massive curriculum changes in English language arts, mathematics, and science across the country (Hanushek, 2009; Sclafani, 2002) as states sought to meet the mandates set forth in NCLB. For years, these changes had been addressed by individual states, working either in isolation or in small groups. This created a patchwork landscape of educational standards in all tested subjects across the country.

State science standards following NCLB were heavily based on the 1993 Benchmarks for Scientific Literacy (BSL) and the 1996 National Science Education Standards (NSES) (Tanner & Allen, 2002). Beginning in 2010, the Carnegie Corporation funded a grant that resulted in a two-stage process that developed the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) which were intended to be adopted verbatim as national standards (Pruitt, 2014). The first stage produced the Framework for K-12 Science Education (National Research Council [NRC], 2012) which delineated what is needed to function as a scientifically literate citizen in the 21st century (Pruitt, 2014) and addresses the changes in scientific knowledge that have occurred since the publication of the NSES and BSL. This initial document served as the foundation and conceptual framework for the NGSS which were developed in the second stage of the process. This second stage was managed by Achieve Inc. and engaged 26 lead state partners and 41 writers to develop the NGSS (NGSS Lead States, 2013).

In April 2013, the NGSS were released and shortly thereafter, Rhode Island became the first state in the nation to adopt the standards. Since then, 19 other states and the District of Columbia have officially adopted the NGSS with more states considering adoption.
Table 1

<table>
<thead>
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<th>NGSS States</th>
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<td>Delaware</td>
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<td>District of Columbia</td>
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<td>Hawaii</td>
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<td>Illinois</td>
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The NGSS departs from current practice and pedagogy at all levels of the K-12 education spectrum, though this departure is starkest at the high school level where the NGSS fail to align with the current model of science instruction. In terms of practice, curriculum sequencing at the high school level has traditionally operated on some formulation of the biology, chemistry, and physics model of science instruction wherein students complete one year of study in each domain (Yager, 2015; Dodick & Orion, 2002). This model harkens back to the Committee of Ten report (Harris, W., Maxwell, W., Nightingale, A., De Garmo, C., & Greenwood, J., 1984) Some schools opt to begin with biology, while others have adopted the Physics First model. The NGSS deviate from the biology, chemistry, and physics structure, instead focusing on the areas of life science, physical science, and Earth and space science (National Research Council [NRC], 2012) and specifically suggest that schools adopt an integrated model of science instruction (NRC, 2012; NGSS Lead States, 2013). Under an integrated model of science instruction the content domains are not separated, students study life science, Earth and space science, and physical science in the same course, often by approaching the study of science thematically. For example, in an integrated science course a unit of instruction on energy could focus the use and transformation of energy in different systems.
While inquiry-based science pedagogy dates back to the 1960s and was strongly reflected in the 1996 NSES, state level standards developed from the NSES and Benchmarks for Science Literacy largely separated inquiry-based and content-based standards (Pruitt, 2015).

Science education has always had a tension between the findings of science and the process of science. Textbooks that reflect an inquiry-based approach to science education have existed since the 1960s and include the Interaction Science Curriculum Project, BCBS Biology, CHEM Study, and PSSC Physics. Mainstream textbooks, which focus primarily on the findings of science, are widely used.

Additionally, state-level science assessments in high school have traditionally focused on measuring the acquisition of factual knowledge rather than the process of developing scientific knowledge or habits of mind (NRC, 2012; Pruitt, 2015; Marx & Harris, 2006). At the same time, programs of science teacher preparation have placed significant emphasis on the teaching of inquiry to pre-service teachers. This creates a significant disconnect between teacher training, practice, and the NGSS at the high school level (Windschitl, & Stroupe, 2017; Bybee, 2014).

**Evidence Justifying the Research Problem**

The NGSS is the most significant change to science education since the publication of the National Science Education Standards (NSES) in 1996 (Yager, 2015). It represents a radical departure in practice with regard to both content and pedagogy from the standards created by states that were based on the NSES. Further the push for integration of the disciplines along with the explicit change in the role of inquiry require students and teachers to approach science content in new ways and challenge old paradigms for addressing content (Bybee, 2014; Pruitt, 2015).
Teacher reactions and resistance to curriculum change are documented in the research literature (Gürses & Helvaci, 2011; Paetcher, 2003; Terhert, 2014). Specific resistance to the use of inquiry among science teachers has also been documented (Rosenfeld & Rosenfeld, 2006). Additionally, teacher resistance to organizational change as a concept is also well established (Achinstein & Ogawa, 2006; Berkovich, 2011; Thornberg, 2014).

**Deficiencies in the Evidence**

Curriculum change of this magnitude, dealing with both content and pedagogy in science education has not been studied with any significant depth. The NGSS are so new that very few research studies on teachers’ adaptation to the new standards have been undertaken and published. This is especially important, given that the new standards will require educators to teach outside their content expertise and enact inquiry-based pedagogy in the classroom.

The purpose of this explanatory sequential, mixed-methods study was to identify and compare the factors that influenced science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS, in the traditional disciplines of biology, chemistry, and physics. The central research question for this study was: *What factors influence high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?*

**The Audience**

By exploring high school teacher perspectives on the NGSS, stakeholders, such as school administrators and superintendents, as well as community partners, such as local colleges and universities, can be better prepared to anticipate, identify, and rectify problems with the implementation of the standards. Understanding teacher perspectives on the NGSS and their implementation will also be helpful in addressing issues of teacher resistance. This research will
be broadly applicable to states in the process of implementation as well as states considering adoption.

**Significance of the Problem**

Success in science education, at the K-12 level, is seen as important in maintaining American economic prominence (NGSS Lead States, 2013; NRC, 2012). Science education has been a focus of American education policy (Ravitch, 2010; Ravitch; 2013; Basile & Lopez, 2015) since the publication of A Nation at Risk (United States National Commission on Excellence in Education, 1983). While significant research has been done in the area of teacher reactions to curriculum change and change resistance (Craig, 2012; Mutch, 2012; Waugh & Godfrey, 1993; Waugh & Punch, 1995; Chi-Kin Lee, 2000), this research has not specifically focused on science education. The curriculum change necessitated by the adoption of the NGSS encompasses shifts in both content and pedagogy that stand in stark contrast to prior models of science instruction and teacher training. The NGSS offers the opportunity to focus curriculum change research on science education, particularly at a time when the current model of science education at the high school level is undergoing a dramatic shift (Yager, 2015). This research will help to inform policy makers, administrators, curriculum developers, and purveyors of professional development how to best support science teachers through this transition.

**Positionality**

In terms of this research, it is important for me to acknowledge that I have been a supporter of the NGSS since their release in 2013. This places me in stark contrast to the teachers with whom I work and many teachers throughout states that have adopted the standards. While my support for the standards and my colleague’s lack of support are meaningless in terms of policy, they do have the ability to influence practice. On a professional level, I changed my
practice because of what is contained in the NGSS and the Framework for K-12 Science Education, the document that informed the construction of the NGSS.

In terms of my classroom practice, I have always viewed myself as a teacher first. This concept of myself as a teacher and then a content specialist (Paechter, 2003) is a key part of my positionality and is especially important in terms of my view of the NGSS, which call for teachers to engage in some level of integrated science instruction (NGSS Lead States, 2013; Pruitt, 2015).

I began my career in a Catholic school teaching church history, an odd position for a secular Jew. I then moved into a split science and math position where I taught both chemistry and algebra. When I moved to public school, my course assignments shifted considerably from year to year. In the last eight years, I have taught biology, chemistry, forensics, environmental science, and physiology. Additionally, I have taught Advanced Placement level biology, chemistry, and environmental science. These experiences have further intensified my view of myself as a teacher first and a content specialist second. Framing my self-concept as a content specialist in biology, the subject that I studied for my undergraduate degree, then as a teacher, would have made the shift to teaching other content areas more difficult, which is necessary under the NGSS. Paechter (2003) asserts that teachers in science and math often see themselves as content specialists, such as identifying as a biologist or chemist, before seeing themselves as teachers.

Furthermore, it is important to acknowledge that my support for the NGSS and the changes in my practice extend beyond what I do in my classroom. I have actively sought out professional development on the standards through offerings from the National Science Teachers Association (NSTA) and graduate coursework at a local college. In addition, I have attended and
presented at both practitioner and scholarly conferences on the NGSS, specifically in the areas of
curriculum development and classroom pedagogy. I have done qualitative research on teachers’
responses to the transition to the NGSS using Bupp’s (1996) model for emotional response to
organizational change as a theoretical framework (Kraus & Shapiro, 2017). Additionally, I serve
as a clinical placement teacher to student teachers at a local college where transitioning to the
NGSS features heavily in the science methods course. I would not be able to serve as a clinical
placement teacher within this program if I were not onboard with the standards and the pedagogy
required to implement them. These interactions and experiences have provided me with a sense
of privilege as it relates to knowledge about the NGSS (Briscoe, 2005).

My professional practice and beliefs about curriculum also inform my positionality as it
relates to the NGSS. According to Schiro’s (2012) Curriculum Ideologies Inventory, I fall
strongly into the social efficiency ideology. “Social efficiency advocates believe that the purpose
of schooling is to efficiently meet the needs of society by training youth to function as future,
mature, contributing members of society (Schiro, 2012, p. 5). Both the NGSS and the
Framework for K-12 Science Education explicitly cite the need to develop college and career
readiness along with scientific literacy in students (NGSS Lead States 2013; NRC, 2012). This
aim falls in line with the social efficiency ideology.

My acceptance of the social efficiency ideology can be traced back to my father. I am the
daughter of a published expert (Shapiro, 1995) in the field of training and quality assurance, not
in the K-12 sphere but the corporate sphere. I was raised in a family where my father brought his
work home every night and where dinner table discussion was an extension of the workday. It
was through this discussion that I was introduced to, and influenced by, the works of Mager,
Skinner, Hiakawa, Bloom, and others. Through this cognitive apprenticeship with my father, I
have come to understand the power and importance of curriculum alignment (Tyler, 2013). This is especially true, as it relates to higher order objectives, like state or national standards. The NGSS serve a set of national standards from which curriculum, instruction, and assessment can be based.

Based on the focus of my professional work experience, which has involved helping students to meet academic standards, it is clear that both an essentialist perspective and a progressive perspective undergird my professional practice and beliefs about curriculum. Essentialism as an educational philosophy is predicated upon the idea that certain core content knowledge is necessary for all students to learn and master (Null, 2007; Bagley, 1911). Progressivism, on the other hand, focuses on the need to prepare students to live, work, and participate as members of a democratic society (Kilpatrick, 1918; Dewey, 2004). The NGSS realign the focus of science instruction from a discipline focused solely on the transfer of knowledge to one where knowledge, skills, and scientific habits of mind are the focus of instruction. From a pedagogical perspective, the NGSS fall more in line with tenets of progressivism, specifically in the way that content knowledge serves as a means for students to explore and engage in the practices of science.

**Research Questions**

The central research question for this study is: What factors influence high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS? The sub-questions for this study are:

1. What factors contribute most to high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
2. What factors contribute most to high school biology teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?

3. What factors contribute most to high school chemistry teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?

4. What factors contribute most to high school physics teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?

5. Why are the identified factors involved in receptivity an issue for biology, chemistry, and physics teachers respectively?

6. How do the identified factors operate in the classrooms and experiences of biology, chemistry, and physics teachers?

**Theoretical Framework**

Windschitl’s Framework of Dilemmas (Windschitl’s Framework) forms the theoretical foundation for this study. The first section, entitled description of the theoretical framework, describes Windschitl’s Framework by defining the different types of dilemmas and situating them within the problem of practice. It then moves to a discussion of the significance of the framework and use of this theoretical framework by contemporary scholars in a number of fields. The next section, entitled justification for the theoretical framework, evaluates and defends the choice of this framework over other options. This is followed by a discussion of the alignment between the problem of practice, research questions, and theoretical framework. The final section, entitled use of the theoretical framework, discusses how the theoretical framework will shape and inform the study.
Description of the Theoretical Framework

Mark Windschitl is the author of this theory and the seminal research on dilemmas in constructivist teaching. His work was heavily informed by the major figures in constructivist educational philosophy and pedagogy. Windschitl’s Framework was built from an examination of the dilemmas that teachers face in implementing constructivist teaching in the classroom. It presents a structure for examining the different types of obstacles that teachers face and can serve as a means to understand the facets of teacher resistance to the NGSS.

Windschitl Framework (2002) defines dilemmas as aspects of “teachers’ intellectual and lived experiences that prevent theoretical ideals of constructivism from being realized in practice in school settings” (p. 132). Other studies that have used this framework have adapted the definition of a dilemma to suit the aims of the study. For instance, Cushion (2013) alters Windschitl’s definition of a dilemma to suit his study on constructivist coaching in sports by defining dilemmas as “aspects of coaches’ intellectual and lived experiences that impact their coaching practice” (p. 61). Using this precedent of adapting the definition of a dilemma, the definition of a dilemma has been modified for the purposes of this study. Here, a dilemma is defined as an aspect of teachers’ intellectual or lived experience that prevents the theoretical ideals of the NGSS from being integrated into classroom practice.

Windschitl (2002) identifies four categories of dilemmas: conceptual dilemmas, pedagogical dilemmas, cultural dilemmas, and political dilemmas. Listed in this manner, the categories of dilemmas teachers experience increase in relation to both the number of participants involved and the number of interactions they encounter.

**Conceptual dilemmas.** Conceptual dilemmas arise from teachers’ understanding of philosophical, psychological, and epistemological perspectives (Orlando, 2014; Windschitl,
2002). Conceptual dilemmas exist within teachers and relate to their understanding of the subject matter or their beliefs regarding teaching and learning.

In terms of the NGSS, conceptual dilemmas take a variety of forms relating to teacher beliefs and subject matter knowledge. For example, rejection of the use of inquiry as an instructional methodology in science would fall under the realm of a conceptual dilemma. Those teachers who view their role in the classroom as the ‘sage on the stage’ (King, 1993), keeper and transmitter of knowledge, encounter a conceptual dilemma.

The Crosscutting Concepts (CCC), one key aspect of the NGSS, link all domains through seven fundamental concepts that exist across all areas of science. In teaching CCC, teachers are encouraged to blur the lines between the traditional disciplines, something which they have not been trained to do, either through the history of their professional practice or through professional education programs.

Conceptual dilemmas are encountered when teachers are required to teach content that is foreign. For example, the NGSS associates plate tectonics with biology, under the study of evolution, as it provides evidence for the theory of evolution. Heretofore, plate tectonics was studied as an Earth and space science concept at the middle school level. A biology teacher with no coursework in Earth and space science, suddenly required to integrate plate tectonics into the curriculum, could encounter a conceptual dilemma.

Additionally, conceptual dilemmas surface when teachers are required to teach content that conflicts with their own personal beliefs. Examples of this include the heavy focus on climate change and evolution, issues about which teachers’ personal views may be in conflict with the content they are required to teach.
**Pedagogical dilemmas.** Pedagogical dilemmas arise from the challenges in designing curriculum and instruction to help students meet the NGSS. It is important to note here that the ‘sage on the stage’ concept defined by King (1993) is not a pedagogical dilemma, as it represents a rejection of inquiry based learning, rather than a lack of pedagogical knowledge. Pedagogical dilemmas arise from challenges to teachers’ pedagogical content knowledge, that is, the ways in which teachers convey content to students (Park & Chen, 2012). The NGSS expect teachers to shift classroom pedagogy largely to an inquiry and project based approach to learning. Haag and Megowan (2015) found that teachers trained in the use of modeling instruction, one type of inquiry-based learning, expressed greater self-assessed readiness to implement the NGSS than their peers who had not received training in modeling instruction.

**Cultural dilemmas.** Cultural dilemmas emerge between teachers and students as the orientation of the classroom is reconstructed to align with the NGSS. Beliefs about classroom culture exist between teachers and students. They are visible in both the demeanor and actions of classroom actors, as well as in the layout of the classroom itself. Both students and teachers tend to be most comfortable with a classroom environment where students are seated in rows and raise their hands to answer knowledge or comprehension level questions. Now, they will find themselves faced with cultural dilemmas in an NGSS classroom, as the priority is collaborative learning and problem solving among students (NRC, 2012; NGSS Lead States, 2013). These are activities that do not align with a traditional classroom structure. The NGSS requires students to begin to act as scientists by developing questions, formulating hypotheses, designing experiments, analyzing data, and justifying conclusions. Students who expect to be lectured to and then assessed solely through tests may push back against this new formulation of classroom
culture, as this type of instruction falls outside their internal constructs of what a science classroom looks like.

**Political dilemmas.** Political dilemmas exist within the broader school community, as the prior norms for science teaching and learning are disturbed. Beliefs about the “what” and “how” of learning in a science classroom extend beyond students and teachers, the immediate actors, to outside actors within the school community such as administrators, parents, and school boards. Political dilemmas also take into account issues of funding, as inquiry based learning is more expensive to implement and sustain than other methods of teaching science. Teachers are beholden to their school or district budgeting policies, and failures on the part of these bodies to adequately fund the materials necessary to implement the NGSS fall under the realm of political dilemmas.

Political dilemmas exist at an even broader level as outside groups, such as lobbyists and religious leaders, push back against content they find objectionable. Science is an area where many topics, such as evolution or climate change, are controversial. Pressure from outside entities has the power to create political dilemmas for both teachers and administrators.

**Summation of the dilemmas as defined by Windschitl.** These four dilemmas exist on a continuum of participants and interactions. At one end are the conceptual dilemmas, reflecting the personal and intellectual concerns of the teacher. At the other end are the political dilemmas, which reflect the structural and public concerns of the school and community. As one moves across the continuum, the number of participants increases and the network of interactions broadens (Windschitl, 2002).

*Figure 1. Continuum of dilemmas.*
Windschitl’s Framework has been used in numerous studies on constructivist pedagogy (Cushion, 2013; Suurtamm & Koch, 2014), implementation of inquiry in science instruction (Lotter, Rushton, & Singer, 2013), and in understanding teachers’ resistance to organizational change (Orlando, 2014). It has also been used to study teacher-educators construction of pedagogy in response to external, often conflicting, mandates (Tillema & Kremer-Hayon, 2005). These studies have contributed to the scholarly literature across a broad range of areas within education.

**Justification of the Theoretical Framework**

The cliché, ‘there is more than one way to skin a cat’, applies as much to identifying a theoretical framework as it does to taxidermy. The choice of one theoretical framework over another drastically impacts the design of a study. This section will justify the choice of Windschitl’s Framework by exploring some of the alternative theories that are commonly used when examining organizational change and defending the choice of Windschitl’s Framework over these alternatives.

**Assessment of alternative theories.** Change curve theories are commonly used as theoretical frameworks for studies on resistance to organizational change and offer the potential to explore teacher resistance. Most change curves identify one or several initial stages in which the change is perceived as unwelcome, and in which individuals exhibit resistance (Elrod & Tippett, 2002). In the Kubler-Ross (1969) model, these stages take the form of anger and denial.
In the Bupp (1996) model, they take the form of shock, denial, anger, and grief. While a change curve theory would allow for examination of resistant teachers’ emotional responses to the NGSS, these frameworks fail to center on how the structure of the school environment influence resistance and teachers’ understanding of the NGSS. They are also not specific to the field of education. In fact, change curve theories are not widely used to examine teacher resistance to change (Kraus & Shapiro, 2017).

**Alignment of the theoretical framework this research study.** The theoretical underpinnings of the NGSS are strongly rooted in constructivist learning theory, which heavily influenced the construction of Windschitl’s Framework. The Practices of Science and Engineering (PSEs) represent the formal incorporation of inquiry in the NGSS. Inquiry in science teaching is based heavily on constructivist learning theory (Gerard, Varma, Corliss, & Linn, 2011; Sanger, 2008). Through inquiry, students engage with scientific problems and concepts through hands-on investigation.

Windschitl’s Framework specifically addresses dilemmas related to fully implementing constructivist teaching methods. It addresses the complexities of the interactions involved. It acknowledges teachers’ understanding of the NGSS, their pedagogical skill, their interactions with students, and the influences of the broader community. In terms of studying teacher resistance to the NGSS, Windschitl’s Framework offers the opportunity to explore the range of factors that influence teacher resistance.

Windschitl’s Framework harmonizes the problem of practice, namely teacher resistance to the NGSS at the high school level, with the research question under investigation. It provides a lens to understand the factors influencing resistance and how they operate at multiple levels. The first four sub-questions support this line of inquiry by examining the different types of dilemmas
faced by high school science teachers in the traditional disciplines of biology, chemistry, and physics. The fifth and sixth sub-questions in this study specifically allowed the researcher to compare the differences in dilemmas between these disciplines, expanding the range of inquiry in Windschitl’s Framework.

The NGSS affects the content of the three traditional high school science courses in different ways. Biology as an area of study remains largely intact. However, under the NGSS, chemistry and physics have been altered dramatically (NGSS Lead States, 2013). A significant amount of traditional content in chemistry and physics has been removed to create a robust body of Earth and space science standards. This content has long been absent within curriculum at the high school level (Yager, 2015), and teachers may or may not have completed college level coursework in these subjects.

Looking at high school science education across all domains, some changes are shared universally. The PSE and the CCC are incorporated into biology, chemistry, and physics through the changes in instruction called for by the NGSS.

**Use of the Theoretical Framework**

The purpose of this study is to identify and compare the factors that influence high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS in the traditional disciplines of biology, chemistry, and physics. The quantitative portion of this study will identify the factors that contribute to teacher receptivity across each of the high school science domains. Windschitl’s Framework provides a structure for classifying and examining factors that influence receptivity at multiple levels. It allows the researcher to move from the level of the individual’s internal interactions with the standards to examine broader external influences on receptivity.
In terms of the qualitative portion of the study, the theoretical framework will provide the initial coding scheme that will be used to examine the data. Interview transcripts will be examined to identify conceptual, pedagogical, cultural, and political dilemmas faced by teachers as they implement the NGSS. Once this data is coded using the initial coding scheme, codes that arise from within the data will be used to further examine and describe the factors, identified by the quantitative research, that contribute to receptivity.

Conclusion

Approaches to science education since No Child Left Behind (NCLB) have focused on the acquisition of factual knowledge. This knowledge acquisition was isolated to specific content silos and was separated from students’ ability to engage in inquiry. This focus on discrete facts within the bounds of high-stakes assessments led to a failure of the inquiry-based reforms of NSES. The NGSS mark a return to the pre NCLB focus in science education in two distinct ways. First, the performance expectations in the NGSS are structured in such a way as to break down the traditional content domains and in favor of an integrated model of science instruction (Bybee, 2014). At the high school level, the NGSS displaces the long-held model where biology, chemistry, and physics typically constitute the primary areas of study. Second, science assessment in the NCLB era focused on the demonstration of students’ acquisition of factual knowledge as separate from inquiry. In contrast, assessment in the NGSS is performance-based, requiring students to demonstrate mastery of inquiry within the context of explaining phenomena.

This research seeks to examine the factors that influence teacher resistance to the NGSS. For the purposes of this study, dilemmas are barriers that arise from teachers’ intellectual or lived experience that prevent them from implementing the NGSS. Like Cushion (2013), the definition
of a dilemma has been adapted to suit the purposes of this study. Windschistl identifies four types of dilemmas: conceptual dilemmas, which are rooted in teachers’ understanding of their content and beliefs about pedagogy; pedagogical dilemmas, which address teachers’ pedagogical content knowledge and the challenges of developing instruction aligned to the NGSS; cultural dilemmas, which address student and teacher expectations of classroom culture and practice; and political dilemmas, which address influences from outside the classroom at a number of levels.

Windschitl’s Framework is a powerful theoretical framework for examining teacher receptivity to the NGSS. Using this framework eliminates the assumption that all factors that influence receptivity occur at the level of the individual teacher. It provides a structure for categorizing and examining factors that influence receptivity at a number of levels that involve a broadening number of participants and interactions.

**Research Design Summary**

This explanatory sequential mixed-methods study identified, described, and compared the factors that influenced high school science teachers’ receptivity to the NGSS. This type of research design consists of collecting data in two phases. The first phase involves the collection and analysis of quantitative data and this data is given priority in the study. The second phase of data collection is qualitative and serves to refine or expound upon the results of the quantitative data (Creswell, 2005; Frankel & Wallen, 2009). The quantitative portion of this study utilized a survey, administered via Qualtrics, to gather data on the population of high school science teachers in states that have adopted the NGSS. The qualitative portion of this study examined the factors related to resistance by using an embedded multiple case study (Yin, 2014).
Chapter 2: Literature Review

This literature review addresses several important themes related to the transition to the NGSS and the process of curriculum change as a whole. First, begins by situating the NGSS within the context of the changes that have occurred in education policy at the federal level. Second, it describes the NGSS in detail, both from the perspective of content and pedagogy. Third, it explores what the literature tells us about how teachers experience curriculum change. Fourth, it provides an analysis of the factors involved in change resistance. Fifth, provides a discussion of change fatigue. Finally, discusses how models of organizational change can be used to understand and predict the process of transition.

How did we get here?

In order to understand where the NGSS came from, it is first necessary to situate the NGSS within the historical context of education in the United States. The standards and accountability movements, the most recent movements in American educational reform, can trace their lineage back to a movement at the beginning of the transition between the 19th and 20th century known as the social efficacy movement (Shepherd, 2000; Spohn, 2008; Waldow, 2014; Ravitch, 2010). Both the NGSS and the Framework for K-12 Science Education harken back to this ideology by citing the need for college and career readiness (NRC, 2012; NGSS Lead States, 2013), as opposed to preparing individuals for manufacturing tasks which was the goal public education in the 19th century.

The social efficacy movement called for the development of standards, or desired outcomes, that schools could use to guide instruction. In essence, the idea was to provide schools with a template of what was needed in the modern workforce and that schools would, in turn, produce the desired outcomes within their students (Shepherd, 2000; Waldow, 2014; Pellegrino
& Hilton, 2013; Ravitch, 2010). While the needs of the workforce have changed over time, the practice of using schooling to develop human capital has remained consistent. The committee that constructed the NGSS and the Framework for K-12 Science Education consisted of members from both the public and private sector. It included scientists, policy makers, teachers, and business leaders working together with the singular focus of identifying what American students need, in terms of science education, to be college and career ready (NRC, 2012; NGSS Lead States, 2013).

Following World War II international competition, first with the Soviets and then later with other nations, influenced science education policy in the United States (Yager, 2000). While no attempt at a national standards document existed in science education during the 1950s or 1960s, the focus of science education was largely driven by the impetus to compete technologically with the Soviets (Bybee, 1995). The 1960s also saw the rise of inquiry science as a method for approaching laboratory investigations, though it is important to note that inquiry in labs during this period was still largely paired with direct instruction as it related to content (Yager, 2000).

Science education reform in the 1970s saw the pendulum swing away from the reforms of the 1950s and 1960s, focusing instead on research in science learning. The reforms of the prior two decades were largely implemented in reaction to the Soviet threat. Project Synthesis, the summation of this research, identified four goals for science education reform: (1) students ability to use scientific information and skills in their own lives; (2) students ability to act as scientifically literate citizens in a democratic society; (3) career awareness; and (4) preparation for future, higher level, academic work in science (Yager, 2000). These stated goals represent a return to the broader ideals of the social efficacy movement.
Project 2061, which commenced in the 1980s, further examined learning in science education. The result of this project produced Science for All Americans which focused on scientific literacy as the goal, rather than the production of scientists (Rutherford & Ahlgren, 1990; Wren, 2014). Science for All Americans largely influenced the development of both the Benchmarks for Science Literacy (BSL) and the National Science Education Standards (NSES) (Yager, 2000; Moreno, 1999), further embedding the social efficiency ideology into American science education. Science for All Americans broadened the profile of science, technology, engineering, and mathematics (STEM) education as an interdisciplinary and interdependent field (Wren, 2014).

The progression of federal education reform from the publication of A Nation at Risk, during the Ronald W. Reagan administration, to the passing of No Child Left Behind (NCLB), during the George W. Bush administration, has fully ensconced the ideology of the social efficacy movement into federal education policy (Gardner, 1983; Ravitch, 2010; Ravitch, 2013). NCLB took the core ideology of the social efficacy movement a step further, by requiring both standards and high-stakes assessments in science, English language arts (ELA), and mathematics (No Child Left Behind [NCLB], 2002; Ravitch, 2010; Ravitch, 2013). In contrast to ELA and mathematics, making adequate yearly progress (AYP) toward proficiency on high-stakes assessments was not mandated in science (NCLB, 2002; Lontok, Zhang, Dougherty, 2015).

Though NCLB mandated science testing, the failure to require AYP has resulted in science receiving less focus than ELA and mathematics (Vogler, 2011). The Obama-era reforms, Race to the Top and the Every Student Succeeds Act, have increased the focus on science by allowing states to use federal funds to develop assessments that include engineering and to increase teacher professional development in science (Heitin, 2016; Ravitch, 2013; Ferguson
2016). It remains important to note that science education still receives less focus than ELA and mathematics, though the gap has narrowed.

**What are the NGSS?**

The NGSS depart from the previous science standards, which were informed by the National Science Education Standards (NSES) and the Benchmarks for Science Literacy (Yager, 2015; NRC, 2012) and will fundamentally alter science instruction (Bybee, 2014; Pruitt, 2015). This is most evident at the high school level, where the focuses of the NGSS are markedly different from the traditional high school curriculum (Yager, 2015). Since the NGSS depart from prior practice in terms of both content and pedagogy, this literature review addresses the changes in content and the changes in pedagogy separately.

Science education, more so than any other field of education, experiences changes in content knowledge because of continued scientific research (Melville, 2008). Take for example, the discovery of the structure of deoxyribonucleic acid (DNA) in the 1940’s. Prior to the discovery of DNA, proteins were believed to be the molecule of inheritance. This single discovery changed how inheritance was taught and introduced molecular genetics to the science classroom. Further discoveries relating to DNA have changed what we know about evolution, development, and phylogeny. All of these changes have been incorporated into science education.

**Science Content in the NGSS**

The NGSS are made up of three components: the disciplinary core ideas (DCI), the practices of science and engineering (PSE), and the crosscutting concepts (CCC) (NGSS Lead States, 2013; NRC, 2012). With respect to the DCI, which can be viewed as the academic content standards, the NGSS changes the information that is to be covered within science classes.
The PSE form the backbone of how science is to be taught and they provide a framework for how the content should be applied by students. The CCC blur the lines between content areas by tracing key themes from one disciple to another (Duncan & Cavera, 2015; Krajick, Codere, Dahnah, Bayer, & Mun, 2014). The three components of the NGSS are combined into performance expectations and are intended to be taught together, seamlessly, with no single component receiving greater emphasis than another (NGSS Lead States, 2013; NRC, 2012; Bybee, 2014; Pruitt, 2015). Teaching the components together is called three dimensional learning (Krajick et al., 2014; NGSS Lead States, 2013; NRC, 2012).

Figure two below illustrates a performance expectation and its component elements. Performance expectations combine the DCI, CCC, and PSE. The performance expectation, HS-LS2-5, states “Students who demonstrate understanding can develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere” (NGSS Lead States, 2013, p.285). By using the phrase “develop a model”, this performance expectation highlights the PSE of developing and using models, while also indicating the CCC of systems and system models. The phrase “illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere” (NGSS Lead States, 2013, p.285) relates to the DCI of cycles of matter and energy transfer in ecosystems as well as energy in chemical processes. This also highlights the CCC of energy and matter because the content of this performance expectation addresses biogeochemical cycles. From the perspective of three-dimensional learning, the PSE, DCI, and CCC in this performance expectation were designed to be taught together, seamlessly, such that the student uses the PSE to engage in learning that facilitates building scientific knowledge of the DCI and CCC.
Figure 2. A sample performance expectation and components.

<table>
<thead>
<tr>
<th>HS-LS2-5</th>
<th>PSE</th>
<th>DCI</th>
<th>CCC</th>
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<tr>
<td>Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.</td>
<td>Developing and Using Models</td>
<td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</td>
<td>Systems and System Models</td>
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The DCI that the NGSS focuses on fall into four domains: physical science, life science, earth and space science, and engineering (NGSS Lead States, 2013). At the high school level, these domains depart from the traditional core content of biology, chemistry, and physics. Significant overlap occurs between the life science standards and a traditional biology curriculum. Chemistry and physics, both physical sciences, are incorporated under the physical science standards. However, the number of physical science standards has been significantly decreased to make room for a robust set of Earth and space science standards, as well as engineering standards. This has resulted in the elimination of traditional topics, from both chemistry and physics, including gas laws, which have historically been part of the chemistry curriculum, and 2-dimensional motion, which was part of the physics curriculum (NRC, 2012; NGSS Lead States, 2013).

In addition to changes in the structure of science instruction, the NGSS also require teachers to address content that is controversial in nature. Issues such as climate change, alternative energy sources, and evolution feature heavily in the NGSS (Colston & Ivey, 2015). These topics have not universally been included in state science standards and, due to their
controversial nature, may create resistance to adopting the NGSS by teachers who do not want to make waves or who hold ideas that contradict the established science (Dawson, 2012; Plutzer, McCaffrey, Hannah, Rosenau, Berbeco, & Reid, 2016).

Under the NGSS framework, the DCI are meant to be taught in an integrated manner. Appendix K in the NGSS (NGSS Lead States, 2013) document charts several paths through the standards at both the middle school and high school level. All of the suggested paths push for integration of the DCIs to some extent. Integrated science, which can be defined as teaching concepts from all domains within a common context (Lambert, 2006), is not new to the NGSS. Integrated science improves student learning and the development of scientific literacy (Hurd, 1997; McComas & Wang, 1998).

The fact that peer reviewed literature, both in the form of empirical studies and position papers, calling for the integration of science instruction exists and goes back to the time period when the Benchmarks of Science Literacy and the NSES was significant. Despite calls for this type of science curriculum, most high schools in the United States maintain a curriculum consisting of the separate subject area silos of biology, chemistry, and physics (Yager, 2015). Compounding this is the fact that state level policies surrounding science education promote the silo approach by certifying science teachers to teach in the specific domains (Carmichael, 2017). Colleges and universities who train science teachers still model their programs around the traditional silos in order to meet state certification requirements and school staffing needs.

The NGSS go beyond merely integrating the traditional science disciplines; specifically, the standards call for integrating science with mathematics and ELA as well as engineering. The NGSS standards document specifically highlights connections to the Common Core State Standards (CCSS) in ELA and math. Teaching integrated science, which includes bridging the
scientific domains, and includes both mathematics and ELA instruction, requires a shift in teachers’ conceptual framework of both their concept of teaching and their specific discipline (Rennie, Venville, & Wallace, 2011). In effect, science teachers need to be applied mathematics and ELA teachers, as well as versed in all of the scientific disciplines.

Both the NGSS document itself, and the Framework for K-12 Science Education, highlight the importance of science, technology, engineering, and mathematics (STEM) education (NGSS Lead States, 2013; NRC, 2012). Yet, STEM education is a term that is frequently misunderstood by students, educators, and policy makers (Bell, 2016). The intense focus on STEM education arose following the Sputnik launch, though the acronym was not coined until the late 1990’s, and since that time STEM education has been seen as essential to American economic viability (Bell, 2016; Bruce-Davis, Gubbins, Gilson, Villanueva, Foreman, & Rubenstein, 2014).

Side two of the NGSS triangle, the CCC, highlights common themes across the scientific disciplines. Along with the DCI, the CCC can be used to construct themes or storylines by which to engage in interdisciplinary instruction. The Framework for K-12 Science Education and the NGSS identify seven CCC: (1) patterns, (2) cause and effect, (3) scale, proportion, and quantity, (4) systems and system models, (5) energy and matter, (6) structure and function, and (7) stability and change (NGSS Lead States, 2013; NRC, 2012). The CCC provide a means for linking content across scientific disciplines and further integrating science instruction.

One example of how a CCC can link scientific disciplines is energy and matter. This concept appears in biology, chemistry, physics, and earth and space science. In biology, energy and matter are addressed in multiple places including trophic relationships and cellular energetics. In chemistry, it is addressed in thermochemistry and chemical reactions. In physics, it
is found in forces and motion. In earth and space science, it is found in biogeochemical cycles and plate tectonics. Energy and matter can be explored through engineering, where students develop solutions to conserve or transform energy and matter. A storyline focused on this CCC pulls together DCIs from all of the domains.

**Science Pedagogy in the NGSS**

In terms of pedagogy, meeting the NGSS requires a commitment to inquiry and engineering as fundamental tools for science instruction (Bryce, Wilmes, & Bellino, 2016; Duschl & Bybee, 2014). Inquiry science can be defined as science instruction that focuses on students developing questions, formulating hypothesis, designing and conducting investigations, and communicating their findings (NRC, 2000). Inquiry science is meant to be an authentic experience of the scientific process that mirrors the process conducted by professional scientists (Liu, Lee, & Linn, 2010; NRC, 2012).

Inquiry science is not a new phenomenon in science education. Without giving it a name, John Dewey advocated for inquiry based instruction (Dewey, 1910) in the early 1900s. Inquiry or enquiry entered the discourse in science education with J. J. Schwab’s (1962) publication of The Teaching of Science as Enquiry. This work highlighted the fact that many of the reforms suggested by Dewey had failed to be enacted and highlighted the fact that science education largely focused on content (Schwab, 1962). From Schwab’s work through the publication of the NSES in 1996, inquiry based textbooks and curricula existed though were not generally part of mainstream science instruction (Wise & Okey, 1983; Lott, 1983). Examples of inquiry-based textbooks include Interaction Science Curriculum Project series, BCBS Biology, CHEM Study, and PSSC Physics.
Inquiry’s mainstream debut came with the publication of the NSES in 1996. Yet, inquiry was largely misunderstood and poorly defined which led to the publication of Inquiry and the National Science Education Standards (NRC, 2000). Inquiry and the National Science Education Standards (NRC, 2000) sought to provide clarity to teachers on the concept of inquiry in the science classroom and guidance on training educators to use inquiry.

It is important to make a distinction between science and engineering. Science seeks to understand the natural world. Broadly, the process of scientific investigation involves observing phenomena, testing hypotheses, and communicating findings. Engineering, by contrast, is a methodology for solving real-world problems (Moore, Tank, Glancy, & Kersten, 2015; NRC, 2012). The process of engineering involves investigating a problem, identifying criteria and constraints for a solution, developing a solution, testing the solution, and ultimately revising that solution. The Framework K-12 for Science Literacy cites two reasons for including engineering along with science “(1) to reflect the importance of understanding the human-built world and (2) to recognize the value of better integrating the teaching and learning of science, engineering, and technology” (NRC, 2012, p.2). Integrating engineering into science instruction is seen as a means to deepen students’ understanding of science concepts in a real-world context (Berland, Steingut, & Ko, 2014).

The PSE make up the third side of the NGSS triangle and are coequal with the DCI and CCC. The Framework for K-12 Science Education and the NGSS specifically delineate eight practices of science and eight practices of engineering; it is important to note that there is significant overlap between these practices. The practices of science are: (1) asking questions, (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics and computational thinking, (6) constructing
explanations, (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information. The practices of engineering are: (1) defining problems, (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics and computational thinking, (6) designing solutions, (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information (NGSS Lead States, 2013; NRC, 2012). Placing the PSE as a coequal third of the NGSS triangle underscores the importance of both inquiry and engineering in science pedagogy.

Although inquiry science is not new, evidence from research suggests that it is poorly integrated into science instruction (Lebak, 2015; Capps & Crawford, 2013). NCLB has proven to be an obstacle to the integration of inquiry in science instruction because measurement of inquiry skills does not occur on standardized tests (DiBiase & McDonald, 2015). Additionally, engaging in inquiry authentically takes time and resources (Songer, Lee, & Kam, 2002). From a pedagogical perspective, this is much like an engineering problem where there are criteria and constraints. Teachers face limits on time, access to resources, and the need to cover a significant amount of content knowledge. Learning science via inquiry takes time; it is not as expedient as lecturing. Additionally, resources are necessary. Students engaging in authentic inquiry must gather data and often will need to conduct an experiment more than once, as they shift their methodology to account for what they have learned (Morrison, 2014). Since there is no such thing as unlimited time, inexhaustible funding, and selective teaching of content, teachers have had to make pedagogical decisions as to how to teach their classes to meet their goals, which, under NCLB, have included the pressure to maximize performance on standardized tests.

Additionally, teacher beliefs about the nature of teaching, learning, and their subject matter play a significant role in pedagogical decisions within the classroom (Bryan, 2003). In
terms of inquiry science instruction, teacher beliefs can prove to be a barrier in implementing inquiry in the classroom (Lotter, Harwood, & Bonner, 2007; Wallace & Kang, 2004). Professional development aimed at increasing teachers’ use of inquiry as a pedagogical tool is mixed, though long-term professional development programs show greater efficacy in terms of sustained implementation (Gerard et al., 2011; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

Teacher beliefs form out of experiences, both their own experiences as a student and their experiences as a teacher (Capps & Crawford, 2013). Teachers, in designing instruction, draw from their own experiences as students, both good and bad, when formulating lesson plans. Additionally, experiences during teaching inform the development of future instruction. Negative experiences with inquiry, either in the teacher’s role or their experience as a student, can inform pedagogical decisions or make teachers hesitant to use inquiry in the classroom.

The PSE can be applied more broadly as a framework of their own in working for social justice because they require students to look at the impact that science and engineering has on people and society. Throughout the NGSS, especially when engaging in engineering tasks, students are asked to design solutions and look at the impact of those solutions. Take standard HS ESS 3-4, students who demonstrate understanding can “evaluate or refine a technological solution that reduces impacts of human activities on natural systems” (NGSS Lead States, 2013, p. 125). The clarification statement for this standard suggests teaching this standard using the topics of climate change or chemical runoff from agriculture. For both options, proposed solutions need to be analyzed in light of the human impacts that they impose; it is no longer merely acceptable to look at science in isolation.
Conclusion

The NGSS introduce a new structure for science education that brings together what researchers in both science and education have learned since the publication of the Benchmarks for Science Literacy and the NSES. They set up a new paradigm for science education, one that vastly broadens the reach of science education, expanding it into ELA, mathematics, and engineering. This new paradigm enshrines inquiry as a key facet of science education as well as providing for the integration of social justice to produce a more scientifically literate citizenry, one that understands what science is and what it is not.

**How do teachers experience curriculum change?**

Curriculum change is not a new phenomenon brought about by the standards and accountability movements, though both have increased the frequency of curriculum change (Glaus, 2014). Prior to these movements, curriculum changes were enacted based on perceptions of student needs, changes in the needs of the workforce, progression of technology, or changes in subject matter knowledge. Currently, curriculum change is ubiquitous; teachers in mathematics, ELA, and social studies are experiencing curriculum change as a result of the adoption and implementation of the CCSS, while science teachers, in states that have adopted the NGSS or are modifying their state standards to be aligned with the NGSS, are experiencing curriculum change. Curriculum change has also occurred in physical education, music, world language, and arts education. In addition, it is also important to note that curriculum change in primary and secondary education as a result of changes in governmental policy is not unique to the United States; similar patterns can be seen in other countries (Leiringer & Cardellino, 2011; Tudball, 2005). This section will explore how teachers experience curriculum change and how the process of curriculum change is supported.
Teachers’ Experiences of Curriculum Change

In discussing teachers’ experiences of curriculum change, it is first important to define what is meant by curriculum change or reform. Curriculum reform spans the spectrum from wholesale change of both content and pedagogy to minor adjustments in either. The NGSS, specifically at the high school level, are an example of wholesale curriculum change where both content and pedagogy are significantly altered. Other examples of this type of change include transitioning from a teacher-made curriculum to a prescriptive curriculum. Following the passage and implementation of NCLB, many teachers experienced this type of change (Spohn, 2009). This type of broad scale curriculum change is disruptive, but rare and often occurs following some external mandate rather than through teacher impetus.

The other side of the curriculum change spectrum, minor adjustments to either content or pedagogy, can arise through smaller-scale curriculum change initiatives or through a teacher’s perception of student needs (Richardson, 1998). Richardson (1990) notes that teachers often make these more minute adjustments to their curriculum. The simplest example of this can often be seen in instances where a teacher modifies a previously taught lesson based on their perception of student needs or their experience of how the lesson unfolded. Prior experience could cause a teacher to extend the lesson time for a science lab activity or modify lab directions. Differences in class structure, such as the number of English language learners, or the math level of the students, could also cause a teacher to modify previously used lessons.

Teacher experiences of curriculum change are more positive when previous materials and methodologies can be adapted to the new curriculum (Parker, Patton, & Sinclair, 2016; Patton & Griffin, 2008). This type of curriculum change falls more in line with the regular, day-to-day practice of teaching and is not perceived as the same level of curriculum change as one where
previous materials and methodologies must be abandoned. For teachers, it is far simpler to take a previously taught science lab and modify it to be an inquiry lab than it is to develop an entirely new lab activity. It is also far easier to modify an existing curriculum rather than developing a new one, specifically, one that incorporates both new content and pedagogy.

**Supporting Curriculum Change Efforts**

Merely mandating curriculum change does not cause the desired changes to occur in classrooms. Teachers must be supported through curriculum change in order to understand the purpose of the change and to help assist them implementing the changes in their classrooms. This section will explore how sensemaking, professional development, and professional learning communities (PLC) can help teachers in the process of curriculum change.

**Sensemaking.** Carlson and Patterson (2015) define sensemaking as a process where participants, by themselves and as a group, come to collectively understand the purpose of the organization. In discussing the NGSS and curriculum change in schools more broadly, this definition can be clarified as the process by which teachers, working both alone and together, come to understand the purpose of both their subject matter and the purpose of the curriculum reform itself. Sensemaking is a critical process because “for teachers to enact change, they must confront beliefs and attitudes as they make sense of new reforms” (Carlson & Patterson, 2015, p.598).

Individual sensemaking occurs when teachers begin to examine the curriculum change. Though not often named or recognized by the individual teacher, positionality plays a significant role individual sensemaking. Classroom experiences, both in the role of the teacher as well as the role of the student, inform the lenses by which teachers investigate change and construct
meaning. This is further informed by teachers’ feelings about their work, their motivation, and their beliefs about their subject matter (Marz & Kelchtermans, 2013; Paechter, 2003).

Collective sensemaking can be defined as “a more or less explicitly shared set of assumptions, norms, values and cultural artifacts that orient, guide and evaluate teachers’ actions” (Marz & Kelchtermans, 2013, p. 15). Collective sensemaking occurs, both formally and informally, within the context of discussion and collaboration. It extends to the unified understanding of the purpose of the school, and the collective understanding of the role of the subject matter. Differences of opinion exist with regard to the purpose of schooling and the role of students studying specific subjects (Schiro, 2012; NRC, 2012; Schiro, 1992).

Sensemaking can occur within the context of formal professional development workshops focused on meaning-making or through informal interaction with the new curriculum (Jantunen, 2016). Sensemaking in the form of professional development workshops occurs where teachers sit down and build meaning around their shared experience and interpretation (Kilgallon, Maloney, & Lock, 2008) of standards or curriculum. One method of approaching this type of professional development, which is different than the professional development discussed in the next section, involves having teachers work together to build instruction or assessment that they will jointly implement in their classrooms. Working together on these types of tasks allows teachers to collaboratively engage with one another to construct meaning. Another methodology involves having teachers engage in sensemaking individually, by building their own lessons that align to the curriculum reform, and then bringing them together to share the lessons and their experiences in conducting them.

These types of activities can also occur informally within the school setting, particularly in cases where common planning time is an established part of the school culture (Haverback &
Mee, 2013). Shared meaning-making occurs when teachers engage in constructing, conducting, and revising common lessons. While less formal, this type of sensemaking occurs as an organic process.

**Professional development.** Effective professional development is an essential part of curriculum change (Supovitz & Turner, 2000). All professional development is not created equal and poorly constructed or delivered professional development decreases the likelihood of successful integration of the proposed changes. Effective professional development requires continued engagement, rather than a one-off session, and engages educators with subject-matter experts (Hough, 2011). According to Wilson (2013), effective professional development, with regard to curriculum change, is focused on a specific content area, is aligned to a set of internal or external goals, is sustained over a period of time, allows teachers to experience the content and methodologies that they will use, and provides direct instruction on how to use new materials.

Professional development, with regard to curriculum change, allows for sensegiving. That is, for leaders at the school, district, state, or national level to inform educators of the change. Sensegiving conveys meaning of the curriculum change that is constructed from outside the organization itself (Carlson & Patterson, 2015). With regard to the NGSS, this type of professional development could include direct instruction on the history of the standards, their construction, or their purpose and goals.

Another variety of professional development seeks to convey the information and skills needed to enact the reforms. This can include direct content instruction, specifically in cases where teachers are being asked to teach content that they themselves have not studied. This is especially important with regard to the NGSS as high school science educators have traditionally
trained to teach one domain, usually biology, chemistry, or physics. Content-specific professional development can fill gaps in teacher content knowledge and correct misconceptions. Professional development can also train teachers in new pedagogies (Kilagon et al, 2008). With regard to science education, this can include topics such as training teachers in using inquiry to teach science (Herrington, Bancroft, Edwards, & Schairer, 2016) or to use probeware for laboratory investigations (Gerard et al., 2011). Modification of pedagogy is more successful when teachers are provided sustained professional development (Gerard et al., 2011, Peneul et al, 2007).

Professional development, particularly in science education, can also involve embedding teachers in authentic research experiences with practicing scientists. This type of professional development can help teachers to further understand the process of scientific inquiry and investigation, allowing them to better engage in those aspects of science instruction within their own classrooms (Hemler, Repine, Manduca, & Carpenter, 2006; Herrington et al., 2016). Engaging in scientific research also has the ability to develop teachers content knowledge (Enderle, Dentzau, Roseler, Southerland, Granger, Hughes, Golden, & Saka, 2014; Herrington et al., 2016).

**Professional learning communities.** A PLC is “a group of teachers who meet regularly with a common set of teaching and learning goals” (Richmond & Manokore, 2011, p. 545). PLCs can exist within a school environment, such as in a department or across departments, as well as between teachers in different schools. PLCs can also involve teachers engaging with educators at other levels, such as college professors and teachers who provide instruction to other grade levels.
The term can also be broadened to include participation in professional organizations (Farmer, 2012). Several different professional organizations exist for science teachers at the national level including the National Science Teachers Association (NSTA), the National Association of Biology Teachers, the American Association of Chemistry Teachers, and the American Association of Physics Teachers. NSTA is broken down into four divisions, based on grade level, that serve science educators from K-16. NSTA also has local chapters in most states that engage educators in their local community. Membership in these organizations provides teachers access to research, publications, and professional development.

Professional organizations, through the publication of journals and conducting of professional development act as sensegivers to their communities. NSTA was involved with the construction of the NGSS. The organization has restructured its conferences and journals to promote teachers’ understanding of the NGSS.

**Conclusion**

Curriculum change is a broad term that encompasses a spectrum of changes. These changes can occur organically in the classroom based on a teacher’s perceptions of student needs or can be externally mandated in response to policy changes at the federal, state, or local level. Teachers can be supported through the process of curriculum change through sensemaking activities, professional development, and participation in PLCs.

**What informs change resistance?**

Change resistance, or the opposition to change, can be informed by a myriad of factors and is not unique to the field of education. This section will describe factors identified in change resistance by empirical research. As these factors operate at multiple levels, they will be discussed, as they exist, within the construct of Windschitl’s (2002) framework of dilemmas.
Conceptual Barriers

Conceptual barriers operate within the individual teacher with regard to their understanding of the subject matter or their beliefs regarding teaching and learning. This section will discuss the conceptual barriers related to teacher beliefs, locus of control, and cost versus benefit analysis.

Teacher beliefs. Teacher beliefs are a significant factor in their reaction to curriculum change. Teacher beliefs directly affect their responses to educational reforms, including curriculum changes. In addressing the transition to the NGSS, this involves examining how teachers’ beliefs about teaching and learning, and their beliefs about their subject matter, affect their approach to content and pedagogy.

Beliefs about teaching and learning. Teachers’ beliefs influence their classroom practice and can be seen as a lens by which teachers approach curriculum. According to Glackin (2016), teacher beliefs inform pedagogical choices, both in the planning and instructional stages of teaching. These beliefs can influence pedagogical choices, grouping techniques, and inclusion of technology. Teachers with more traditional belief systems, with regard to teaching and learning, tend to adopt more concrete, lecture-based instructional strategies (Laplante, 1997). Lederman (1999) found that the effect of teacher beliefs on instructional practices was lessened by teaching from a scripted curriculum wherein teachers do not have the freedom to make modifications.

Changes in pedagogy, particularly those that involve a significant shift from where teachers are to where they either need or want to be, often need to be accompanied by changes in beliefs about teaching and learning (Tam, 2015). Those that occur organically, that is not out of any sort of mandate, involve teachers changing their beliefs on their own. This can involve professional development or engagement with a PLC, but in this case the driving force for the
change comes from the individual teacher. Changes that result from forces applied from outside the individual teacher can also involve professional development or engagement with a PLC, though in this case the driving force comes from outside the teacher.

**Beliefs about content.** Teacher beliefs about their particular discipline, with respect to what subject matter is and is not included, also informs how they approach instruction (Muma, Martin, Shelley, & Holmes, 2010) and how they respond to curriculum change (Paechter, 2003). Science is an area in which content knowledge is constantly shifting because of continually occurring scientific work and discovery. Moreover, science is an area where some of the content, particularly evolution and climate change, are politically charged issues (Lombardi & Sinatra, 2013). In an explicitly stated effort to develop scientifically literate citizens (NRC, 2012; NGSS Lead States, 2013), the NGSS addresses these politically charged issues at all grade levels.

Teachers’ beliefs about the purpose of science education also heavily inform teachers’ reactions to the NGSS. For teachers who hold the position that the main purpose of science education is for students to learn and internalize subject knowledge, many of the foundational ideas embedded in the NGSS will be antithetical to their own professional beliefs (Anderson, 2015; Glackin, 2016) and hence will cause resistance to change (Paechter, 2003).

**Conclusion.** Teacher beliefs are not static, they can and do change based on experiences (King, Shumow, & Lietz, 2001). Experiences that change teacher beliefs can include interaction with students, professional development, and participation in a PLC. A teacher’s beliefs can directly affect how they approach teaching and learning in their classroom. In science, where some topics are controversial, teacher beliefs can affect decisions as to whether or not to teach material or influence teacher’s comfort in teaching that material (Plutzer et al., 2016).
**Locus of control.** Curriculum change is often forced from above, rather than as a result of what teachers assess as being the best option for their students (Richardson, 1998). Changes in education policy at the federal level, particularly since the enactment of NCLB, have intensified the frequency of curriculum change, as schools search for ways to maximize performance on standardized tests (Ravitch, 2010; Ravitch, 2013). Forced curriculum change of this nature limits teacher freedom and engenders negative feelings towards the change (Paechter, 2003). At the same time, the curriculum publication industry has become more powerful, as it relates to dictating teaching and learning in classrooms (Rodriguez, 2015), further disempowering teachers and limiting teacher agency. In response to some of the mandates in NCLB, some schools have adopted prescriptive curricula that limit or eliminate teacher choice (Ravitch, 2010; Ravitch, 2013; Robinson & Aronica, 2016).

Resistance to the implementation of the NGSS, both in terms of content and pedagogy exists (Haag & Megowan, 2015). Simply mandating a curriculum change will not in and of itself change the curriculum, unless steps are taken to help all stakeholders and actors to understand the change (Priestley, 2011). Buy-in is not created though mandates. Rather, buy-in is created though convincing stakeholders that change is meaningful and beneficial. They involve intentionally shifting teachers’ beliefs to align with the proposed change. Buy-in is also created by supporting teachers through the change process.

**Cost versus benefit analysis.** Curriculum change is a multifaceted process that involves many stakeholders and challenges the professional practice of teachers. “Curriculum change requires a significant investment in time and effort from the teachers enacting it, doubts about the ultimate value the institution would place on these efforts might undermine the process” (Venance, LaDonna, & Watling, 2014, p.1002). If teachers have particularly strong positive
attitudes toward the curriculum that is being replaced, those attitudes will negatively bias their cost benefit analysis (Mellegård, & Pettersen, 2016).

According to Waugh & Godfrey (1993), in order to support a change, teachers must determine that the costs of implementing change are outweighed by the benefits. The cost of curriculum change for teachers is the increased work brought about by the need to abandon or revise previously constructed lessons, materials, and assessments (Waugh & Punch, 1983; Chi Kin Lee, 2000). Benefits can come from increased recognition, increases in student achievement, and improved alignment between teacher interests and course content (Waugh & Godfrey, 1993).

**Conclusion.** Teacher beliefs, locus of control, and cost versus benefit analysis, are all factors that operate within the individual teacher. These factors can influence teachers’ attitudes toward a curriculum change. Within the context of the change of NGSS conflicts can arise across all of these factors.

**Pedagogical Barriers**

Pedagogical barriers to NGSS implementation operate within the classroom dynamic between teachers and students. They encompass teachers’ perceptions of the practicality of the NGSS and pedagogical content knowledge as both influence resistance. They also encompass pragmatic concerns about implementing the NGSS.

**Perceived practicality of the NGSS.** Perceptions of the practicality of a curriculum change can influence teachers’ attitudes. Issues of practicality arise in terms of classroom environment and resources (Waugh & Godfrey, 1993). Haag & Megowan (2015) found that time and resources were perceived as barriers to implementing the NGSS.

Inquiry science takes longer than direct instruction delivered through lecture and requires resources that enable students to engage in scientific investigations (Morrison, 2013; DiBiase &
McDonald, 2015; Krajcik, Blumenfeld, Marx, Bass, & Fredericks, 1998). Inquiry not only requires additional class time, it also demands additional time for teacher preparation (Songer, Lee, & Kam, 2002).

Inquiry science requires greater resources than traditional science instruction (Pozuelos, Travé González, & Cañal, 2010). Resources to implement inquiry-based instruction have long been viewed as a problem for urban schools (Songer, Lee, & MacDonald, 2003). Resources vary by subject and can include textbooks, lab equipment, chemical reagents, laboratory specimens, and technological resources. While some of these materials are reusable, others are consumable and must be replaced every year. Added to this is the problem of equipment breakage, which increases as student use increases.

**Pedagogical content knowledge.** Pedagogical content knowledge (PCK) is teachers’ knowledge of how to formulate instruction that allows students to master content (Lederman & Gess-Newsome, 1992). Teachers must be able to translate their understanding of content into classroom instruction that students can grasp. That is, PCK is an amalgamation of both content knowledge and pedagogical knowledge.

PCK is specific to different academic domains and thus, is not interchangeable (Schnider & Plasman, 2011). A history teacher has PCK that is specific to history, that PCK is largely not transferrable to math or physics. The same can be said within the sciences. As an example, biology teachers’ PCK is different from that of physics teachers.

**Pragmatic concerns.** Pragmatic concerns in curriculum implementation include problems with classroom management, student expectations of instruction, and concerns about student achievement (Chi-Kin Lee, 2000; Peers, Diezmann, & Watters, 2003). Issues with classroom management have been documented in the research literature as teachers...
inexperienced with inquiry struggle to manage student behavior (Eick, Ware, & Williams, 2003; Harris & Rooks, 2010). Students develop their expectations of classroom instruction and their role in it as they progress through their education. Marked changes to these expectations can be met with resistance or reluctance from students.

**Cultural Barriers**

Cultural barriers operate between actors within the school environment. This includes interactions between teachers affected by the change, as well as interactions between teachers and administrators. This section will discuss cultural barriers of teacher participation in decision making, attitudes of colleagues, and administrator support.

**Participation in decision making.** Teacher participation in the decision making process of curriculum implementation is important in building support (Fasso, Knight, Purnell, 2016; Ho, 2010). Participation in the change process can provide ownership and a sense of control over the ultimate formulation of the change in a particular setting (Harvey & Broyles, 2010; Lines, 2004). In terms of curriculum change, this can occur by allowing teachers the opportunity to participate in the process of curriculum development or in the process of selecting a premade curriculum. This allows actors to contribute to the end result, in this case a curriculum that they can enact in their classrooms and of which they can feel some level of ownership.

**Colleague attitudes.** In any organization, some individuals exert more influence than others. In biological systems, organisms that fulfill this role are called keystone species. The health and stability of a biological system is moderated by the actions of the keystone species. Examples of keystone species include sea otters in the Pacific Northwest, or starfish in tide pools. Keystone individuals exist within organizations and perform a similar role. When these individuals vocally resist change, their resistance influences the behaviors, opinions, and actions
of those around them (Westover, 2010). In organizations, these keystone individuals can be seen as allies when they are vocal advocates for the change and obstacles when they are not.

**Administrator support.** Leadership in the face of organizational change can be critical to the success of the change (Liu & Perrewé, 2005). Leaders act as sensegivers by helping their subordinates to rationalize the meaning of the change (Randall & Proctor, 2008). To support curriculum change, principals must articulate a vision for change, create a positive school culture and climate, support teacher growth, monitor instruction, and provide teachers with the resources needed to implement the change (Spillane, Halverson, & Diamond, 2004).

**Political Barriers**

Political barriers operate between the school and the broader society. The attitudes and actions of parents, school district leadership, and political leadership can affect teachers’ attitudes toward change (Chi-Kin Lee, 2000). Parents, depending on their own views, can be forces for or against change (Tytler, 2010). Topics in science education, such as evolution and climate change, are seen as politically charged and legislative efforts to undermine science education have been taken in a number of states (Binns, 2013).

**Conclusion**

Barriers to educational change exist at multiple levels and operate between different actors (Windschitl, 2002). Conceptual barriers operate within the individual teacher and include teacher beliefs, origin or change, and cost versus benefit analysis. Pedagogical barriers operate between teachers and students in the classroom. Pedagogical barriers include perceptions of the practicality of the change, a teacher’s pedagogical content knowledge, and student expectation of classroom instruction. Cultural barriers expand the network of interactions to the school community. Cultural barriers include decision making structure, colleague attitudes, and
administrator support. Political barriers expend the network of interactions beyond the school community to the district, local, and state level where actors outside the system are able to exert influence. Understanding the levels at which barriers to change exist and the network of interactions in which they operate is important when considering the steps that need to be taken to facilitate educational change.

**What is Change Fatigue?**

Change in schools is ubiquitous. Change fatigue is defined as the “perception that too much change is taking place (Bernerth, Walker, & Harris, 2011, p. 322). Practicing teachers face change in many aspects of their careers beyond curriculum (Orlando, 2014). Change fatigue increases throughout the duration of a teacher’s career (Costa & Silva, 2012) as experience of change builds up. Teachers with longer careers are more likely to be affected by change fatigue due to the accumulation of their experiences. Veteran teachers, those with more than a decade of experience in the classroom, have seen the rise and fall of change initiatives; teachers with two or more decades of classroom experience have seen this occur to an even greater degree. This constant environment of change sends an “unrelenting message from educational authorities that teachers’ well-established practices are no longer good enough” (Orlando, 2014, p. 428).

**How is Change Explained?**

The process of curriculum change is just that, a process. It involves teachers making a transition from one way of approaching content and pedagogy to another. It does not happen overnight. A number of change curves, that is, models of the process of organizational change, have been constructed (Coetsee, 1999; Elrod & Tippett, 2002). These change curves plot the course from initial exposure to change, such as the introduction of a new set of academic
standards or a change in organizational process, through implementation and acceptance. All of the stages of change are influenced by teachers’ prior experiences and beliefs.

Several different models of change curves exist, though all share common themes (Elrod & Tippett, 2002; Sotelo & Livingood, 2015). In general, the initial moment of the introduction of change is generally followed by a period where productivity, motivation, or views of self-efficacy decreases (Elrod & Tippett, 2002; Liu & Perrewe, 2005). Under Lewin’s model of organizational change, this period where the status quo is disrupted is known as unfreezing (Lee, 2006). A middle transitional period follows this wherein productivity, motivation, and self-efficacy reach their lowest point and begin to increase. Under Lewin’s model this stage is called moving and it is the point where most of the transition work occurs. The ending transitional period sees an increase in productivity, motivation, and self-efficacy as individuals become proficient in their new roles or with new skills. This period, identified by Lewin as refreezing, persists until a new change comes about.

**Conclusion**

For science teachers, the NGSS are just one example of organizational change that affects the way that teachers navigate their role on the classroom. In the United States, policy shifts and increased knowledge have caused significant changes in the way that science education is approached and implemented. The NGSS formulate and describe what students need to know and be able to do to be considered scientifically literate individuals in the 21st century. In addition, owing to the manner in which they were constructed, they articulate what scientists, business leaders, and teachers believed to be the knowledge and skills that students will need to be prepared for college and careers.
Change resistance is a feature of organizational change. Individuals tend to lean toward the status quo, preferring to continue to engage in established practices. The NGSS, particularly at the high school level, depart from established practice. Changes in both content and pedagogy challenge teachers to reformulate their existing practices. Change resistance is informed by teacher beliefs and prior experiences of change. An additional facet of change resistance is change fatigue, wherein repeated experiences of organizational change cause an individual to be predisposed to distrust or resist change.

Organizational change occurs across all fields, as processes shift as a result of new demands, regulations, or knowledge. A result of this is that the process of organizational change, including curriculum change, has been studied through a number of lenses and in a number of domains. Several different models have been constructed to explain how actors within a system approach the process of change and how the experience of change affects their emotional state and productivity.

Understanding change as a process, particularly one that contains both an emotional and performance component, is critical to understanding how teachers will approach, process, and ultimately implement the NGSS. Attachment to content topics and practices that are no longer relevant need to be addressed by change agents in order for teachers to move through the transition process. Additionally, the information provided in these models provides leaders with a sense of how the process of implementing the NGSS will unfold for the science teachers who will need to implement the standards in their classrooms.
Chapter 3: Methodology

Research Questions

The purpose of this explanatory sequential, mixed-methods study was to identify and compare the factors that influenced science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS, in the traditional disciplines of biology, chemistry, and physics. The central research question for this study was: What factors influence high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS? The sub-questions for this study are:

1. What factors contribute most to high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
2. What factors contribute most to high school biology teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
3. What factors contribute most to high school chemistry teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
4. What factors contribute most to high school physics teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
5. Why are the identified factors involved in receptivity an issue for biology, chemistry, and physics teachers respectively?
6. How do the identified factors operate in the classrooms and experiences of biology, chemistry, and physics teachers?

The central research question for this study was designed to allow the researcher to examine the factors involved in receptivity to the NGSS both quantitatively and qualitatively, thus identifying the strength of the factors involved in receptivity and describing teachers’
experiences of those factors. The NGSS are based primarily on the document published by the National Research Council called A Framework for K-12 Science Education (NRC, 2012). This document, which is based on research on science learning since the publication of the NSES in 1996, as well as changes in scientific knowledge, specifies the curricular shifts needed to improve science education in the United States. The Framework for K-12 Science Education shifts science education to a three dimensional model where no single dimension is of greater value than another (NRC, 2012; NGSS Lead States, 2013; Krajick et al., 2014). The Framework for K-12 Science Education directly advocates for interdisciplinary science instruction at all levels (NRC, 2012). This idea is in direct opposition to the traditional format of science instruction at the high school level where students study subjects in isolation and are taught by teachers trained in a specific content area.

In all of the research questions, the term “curricular” is used very broadly. It includes the changes brought about by all three dimensions and the push toward three dimensional learning. The CCC blur the lines between the scientific disciplines allowing for life science, physical science, and earth and space science concepts to be taught together. The DCI specify the content to be taught and contain distinct shifts from the traditional content of biology, chemistry, and physics. The PSE enshrine inquiry based pedagogy (NRC, 2012; NGSS Lead States, 2013).

Sub-questions one through four will addressed quantitatively. Sub-question one is designed to look at the factors involved in receptivity holistically, across the entire population of high school science teachers in NGSS states. Sub-questions two through four look at the factors involved in teacher receptivity to the NGSS across the domains of biology, chemistry, and physics respectively. The dependent variable for these analyses is receptivity to the NGSS and
the independent variables are the factors that influence receptivity. These variables will be discussed in greater detail later in this chapter.

Each of the traditional domains is affected differently by the transition to the NGSS. Biology, under the NGSS, is the subject that experiences the smallest shifts in content. Changes related to the PSE and the CCC still exist, but the majority of topics covered in a high school biology class will not change (NGSS Lead States, 2013). Chemistry and physics encounter significant changes across all three dimensions of the NGSS. These shifts include significant changes to traditional content. Also, chemistry and physics bear the brunt of responsibility for integrating earth and space science (NGSS Lead States, 2013). Earth and space science is not a traditional high school content area. Many teachers lack college level coursework in Earth and space science and, in many states no high school level certification exists for this area. All three disciplines must contend with the addition of engineering design (NRC, 2012; NGSS Lead States, 2013).

Sub-questions five and six were addressed qualitatively. These questions allowed for a detailed and nuanced description of how teachers understood and experienced the factors identified by the quantitative analysis in their professional practice. Sub-question five examined the question of why the factors identified by the models are important in terms of teacher receptivity while sub-question six sought to examine, in detail, how teachers experienced the factor within their professional practice. For the three traditional domains, these sub-questions attempted to explain the factors identified by the models and allowed for a cross case analysis of the experience of common factors.
Research Design

This mixed-methods study utilized an explanatory sequential research design. This type of research design consisted of collecting data in two phases. The first phase involved the collection of quantitative data and this data was given priority in the study. The second phase of data collection was qualitative and serves to refine or expound upon the results of the quantitative data (Creswell, 2005; Frankel & Wallen, 2009). According to Yin (2014) “mixed-methods research can permit researchers to address complicated research questions and collect a richer and stronger array of data than can be accomplished by any single method alone. (p. 65-66)” While the research question in this study could be pursued as a purely quantitative or purely qualitative study, the use of a mixed-methods design allowed for the building of a more powerful understanding of the factors that influenced high school science teachers’ receptivity to the NGSS.

The quantitative portion of this study utilized a survey and the receptivity to change instrument (Chi-Kin Lee, 2000) to gather data that was used develop a regression model. Multiple linear regression (MLR) is a statistical analysis that allows a researcher to determine the correlation between a criterion variable and a series of predictor variables (Frankel & Wallen, 2009). This model assisted in the identification of the factors that held the most weight in teachers’ receptivity to the NGSS.

One challenge, which is particularly pronounced with the use of any multiple regression statistic, is the need for a very large, depending on the number of independent variables, representative sample. To address this challenge, a national sample was drawn from high school science teachers in states that have adopted the NGSS. Currently 19 states and the District of
Columbia have adopted the NGSS. The positive side of this challenge was that results drawn from a national sample may have broader generalizability than results from a regional sample.

The qualitative portion of this study examined the factors related to receptivity by using an embedded multiple case study. Specifically, this study utilized Yin’s (2014) case study within a survey arrangement. This multiple embedded case study, according to Yin (2014) a Type 4 design, focused on the three traditional content areas of biology, chemistry, and physics. Each of these content areas forms the context for examining the issue of receptivity. The sample for this portion of the study was drawn from the larger quantitative data set. Pursing this as a multiple case study allowed for cross case analysis and honors the fact that high school science disciplines have traditionally been viewed as fully separate entities.

**Site and Sampling**

As of this date, 19 states plus the District of Columbia have adopted the NGSS. This research study focused on high school teachers in the traditional disciplines of biology, chemistry, and physics within states that have adopted the NGSS. The NGSS are the most significant change in science education since the publication of the NSES in 1996, and represent a radical departure from prior practice in terms of both content and pedagogy (Bybee, 2014). Both focus, in terms of content, and the pedagogy necessary to teach the content under the NGSS, are markedly different from prior practice (Bybee, 2014; Pruitt, 2015; Yager, 2015; Krajick et al., 2014). In the four years since the publication of the NGSS, practitioner journals, including the American Biology Teacher, the Journal of Chemical Education, and The Physics Teacher have all published articles that to one extent or another question how the standards will affect content and instruction in the traditional disciplines (Yager, 2015; Cooper, 2013; Blanton, 2012). This type of discourse is also evident in the professional communities of science teachers,
both online and at various forums hosted by these organizations. One example of this can be found in the NSTA online forum on the NGSS where teachers discuss how the NGSS will impact content and instruction (NSTA, nd.).

It is impossible to determine the exact number of science teachers impacted by the adoption of the NGSS as state level data on the number of science teachers is not published. Based on data from the most recent Schools and Staffing Survey from the National Center for Education Statistics, there are approximately 126,000 high school science teachers nationwide (Hill & Stearns, 2015). Of these, 89,400 teach in the traditional disciplines of biology, chemistry, and physics. Table two illustrates the breakdown of high school science teachers by subject area, based on Hill and Sterns (2015) analysis of the Schools and Staffing survey. The sample for this study included teachers who are certified in one of the traditional disciplines and currently teach biology, chemistry, or physics. In order to be included in this sample, the teachers must: work in a state that has adopted the NGSS and be certified in at least one of the traditional content areas.

Table 2

<table>
<thead>
<tr>
<th>Subject</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>51,900</td>
</tr>
<tr>
<td>Chemistry</td>
<td>24,000</td>
</tr>
<tr>
<td>Physics</td>
<td>13,300</td>
</tr>
</tbody>
</table>

In terms of the quantitative portion of this study, an electronic survey was disseminated through a number of modalities. Membership in professional organizations, such as National Science Teachers Association and the National Association of Biology Teachers provided access to teacher listservs. Most states have listservs of teachers in the discipline specific domains managed by the state department of education and the state science teachers associations. Use of
these listservs was also solicited. Teachers were sent an email invitation to complete the survey and were provided with a link to the survey.

This sampling strategy is not without its disadvantages. Due to their nature, survey studies are inherently plagued by certain weaknesses that affect the data gathered. Nonresponse is one obstacle, as nonresponding individuals may have attitudes that are markedly different from those who do respond. Consequently, conclusions drawn from the data may be misleading (Frankel & Wallen, 2009). Participants made the decision to complete the survey. Based on this, it would be unwise to draw a conclusion based on the responses that X percentage of teachers, a descriptive statistic, are resistant to the NGSS. Once this larger data set was obtained, responses could be isolated which correspond to the various analyses specified in the quantitative sub-questions.

In terms of the qualitative part of this mixed-methods study, participants were solicited through the initial survey instrument by asking if they would consent to be part of a follow-up study. Again, solicitation of volunteers potentially biases the data gathered. Those who consented to follow-up were asked to provide an email address. Participation in this part of the study was incentivized. In order to gather sufficient data to build three cases, five to seven participants from each content area were interviewed.

**Data Collection**

This section discusses the data collection procedures that were used in this study. As this is an explanatory sequential mixed-methods study, both quantitative and qualitative data were gathered. In this type of study, quantitative data gathering and analysis preceded qualitative data gathering and analysis. Information on quantitative data collection is discussed first and then followed by a discussion of the qualitative data collection.
Quantitative Instruments

In order to address the quantitative research questions, a survey was conducted through Qualtrics to gather data. A copy of this survey is provided in Appendix B. This survey included: 1) a section to gather demographic data which included state, gender, age, subject area, level of education, undergraduate major, certification area, professional memberships, participation in NGSS professional development, school district type, school type, and self-assessed knowledge of the NGSS, 2) the receptivity to change instrument (Chi-Kin Lee, 2000), and 3) a section to recruit teachers for the follow-up qualitative study.

The demographic data was used in the construction of the model in the first research sub-question and was utilized to isolate samples for the remaining analyses. Table 3 shows the types of variables in the demographic survey.

Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Nominal</td>
</tr>
<tr>
<td>Age</td>
<td>Continuous</td>
</tr>
<tr>
<td>Years of teaching experience</td>
<td>Continuous</td>
</tr>
<tr>
<td>Subject area</td>
<td>Nominal</td>
</tr>
<tr>
<td>Level of education</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Undergraduate major</td>
<td>Nominal</td>
</tr>
<tr>
<td>Certification area</td>
<td>Nominal</td>
</tr>
<tr>
<td>Professional memberships</td>
<td>Nominal</td>
</tr>
<tr>
<td>NGSS professional development</td>
<td>Nominal</td>
</tr>
<tr>
<td>State</td>
<td>Nominal</td>
</tr>
<tr>
<td>School district type</td>
<td>Nominal</td>
</tr>
</tbody>
</table>

The receptivity to change instrument (Chi-Kin Lee, 2000) was created to measure teacher receptivity to a curriculum change and contains seven sections. All data gathered within this instrument was ordinal. The first section contains nine items that measure participant attitude toward the curriculum change. Sections two through seven are measured using a seven point
Likert scale. The second section contains seven items and measures non-monetary cost-benefit analysis of the curriculum change. The third section contains five items and measured the perceived practicality of the curriculum change. The fourth section contains six items and measured issues of concern associated with implementing the curriculum change. The fifth section contained six items and measures school support for the curriculum change. The sixth section contains five items and measured other support for the curriculum change. The final section contains five items and measured behavioral intentions toward the curriculum change. Reliability measures, Cronbach’s alpha, are provided for each of the subscales in table 4.

Table 4

<table>
<thead>
<tr>
<th>Sub-scale</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>0.8050</td>
</tr>
<tr>
<td>Non-monetary cost-benefit analysis</td>
<td>0.8942</td>
</tr>
<tr>
<td>Perceived practicality</td>
<td>0.8101</td>
</tr>
<tr>
<td>Issues of concern</td>
<td>0.8081</td>
</tr>
<tr>
<td>School support</td>
<td>0.8363</td>
</tr>
<tr>
<td>Other support</td>
<td>0.8737</td>
</tr>
<tr>
<td>Behavioral intentions</td>
<td>0.9291</td>
</tr>
</tbody>
</table>

As this instrument was published in its entirety in the Journal of Curriculum Studies, seeking permission from the author for its use was not required. Modifications of the wording of items was made to focus the survey on the NGSS. Other researchers have made similar modifications to this instrument in order to examine other curriculum changes (Thomas, 2014). Where the terms “Guidelines” and “EE” are used in the survey, they were replaced with NGSS or other NGSS specific vocabulary. See the comparison of item wording in appendix A.

At the end of the survey, an additional section was included to identify potential participants for the qualitative part of this mixed-methods study. Those completing the survey
were given the opportunity to provide contact information for a follow-up interview which was conducted using phone or video conference.

**Quantitative Procedures**

Several strategies were used to disseminate the survey. First, membership in the National Science Teachers Association and the National Association of Biology Teachers provided access to organizational listservs through which the survey could be disseminated. This tool was limited in that dissemination of the survey could not be restricted to only NGSS adopting states. As such, data from surveys of teachers from non-NGSS states needed to be sorted and eliminated prior to analysis. Another method of dissemination involved using state science teachers association listservs. Most states have a state-level science teachers association.

Once approval was granted for this study, an initial invitation to complete the survey was sent through the listsevrs and collected email lists. Two weeks later, a follow-up invitation was be sent. No compensation was offered to participants for completing the survey. The survey remained “live” for one month, at that time it closed and data analysis began.

**Qualitative Instruments**

Qualitative data were gathered through the use of semi-structured interviews. This interview protocol was closely aligned with the theoretical framework, Windschitl’s (2002) framework of dilemmas. A copy of the interview protocol was included in Appendix C. All interviews were audio recorded for transcription purposes. Prior to the interview, participants were provided with an outline of the topics that would be covered during the interview.

**Qualitative Procedures**

Once the quantitative data had been analyzed and the models have been generated, the second stage of data collection began. This qualitative phase of data collection was designed to
provide additional information on receptivity among biology, chemistry, and physics teachers. Five to seven teachers from each domain, who completed the initial survey and consented to follow-up, were contacted for interview.

**Data Analysis**

This section discusses the data analysis procedures that was be used in this study. As this was an explanatory sequential mixed-methods study, information on the quantitative data analysis is discussed first. This discussion includes a description of the data cleaning procedures that were used and the statistical analyses to be performed. All statistical analyses were conducted using SPSS.

Following the discussion of the quantitative portion of the study, the qualitative data analysis procedures are discussed. Details on transcription, coding, case construction, and cross-case analysis are described. NVivo, qualitative coding software, was used in the management and analysis of the qualitative data.

**Data Cleaning**

This study utilized a mixed-methods, explanatory sequential design to examine teacher receptivity to the NGSS. The data for the quantitative portion of this study was collected via Qualtrics. Qualtrics allowed researchers to extract their data as an Excel file, which could be imported into SPSS. Once the file had been imported into SPSS, information on each of the variables was entered. The process of entering information on variables included identifying the type of variable, naming the variable, assigning an abbreviation to the variable, and inputting identifiers for the numeric codes of nominal and ordinal variables.

The demographic section of the survey was utilized in data cleaning prior to analysis. This allowed the researcher to identify submissions that came from teachers not in NGSS states.
or from teachers who did not fit the subject area and grade level criteria for participation. This data was stored in a password-protected file on the researcher’s computer.

Once the data had been cleaned and imported into SPSS, some transformation of the data was required. The survey instrument being utilized for this study had seven separate sub-scales that were measured through the use of a Likert scale. Composite variables for each sub-scale were created by calculating the summing the relevant items in all of the sub-scales.

**Statistical Analysis**

Regression analysis allowed the researcher to examine the relationship between a criterion, or dependent variable, and a series of predictor variables, or independent variables. Various types of multiple regression exist: multiple linear regression (MLR), multiple logistic regression, and polytomous universal model (PLUM) (Mujis, 2011).

MLR was determined to be the appropriate analysis for the quantitative research sub-questions, one through four, in this study as the dependent variable was continuous. Multiple logistic regression was used in the case of a binary dependent variable and PLUM was used for ordinal dependent variables (Mujis, 2011). Multiple logistic regression and PLUM were not appropriate analyses in this study as the dependent variable was neither binary nor ordinal.

MLR can handle a broad range of relationships between independent and dependent variables. Several assumptions must be met in order to use MLR. The first assumption was that the dependent variable is continuous. The first subscale in the receptivity to change instrument was used to measure participant attitude to the NGSS. This subscale was used to calculate a scale of receptivity. The second assumption was that the factors used as predictors in the models must be independent of one another. This assumption tested by calculating the tolerance levels of the
independent variables. Lastly, a large sample size was required for statistical power (Osborne, 2015).

To answer the quantitative sub-questions, four MLR will be constructed. The first model was holistic and includes science teachers from all disciplines. The three subsequent models only included teachers from one of the disciplines. These models allowed for differences in receptivity to be examined across the disciplines.

Qualitative Data Analysis

Following the completion of the quantitative analysis, qualitative data was gathered to better understand the results and probe unanswered or resulting questions. This qualitative data was gathered through interviews with survey participants who consented to follow-up while completing the survey. Once the interviews were conducted, they were transcribed by a transcription service. Transcripts and audio files were maintained in a password protected file on the researcher’s computer.

Sub-questions five and six were qualitative and were designed to provide a detailed explanation of the factors identified by the models. Three cases, one for each of the domains, was constructed to support the associated quantitative sub-question. Finally, a cross case analysis was conducted to compare qualitative findings between the cases.

A priori codes, taken from the theoretical framework, were used in the initial coding of the data. Windschitl’s (2002) framework identifies four types of dilemmas: conceptual, pedagogical, cultural, and political. Once the data was chunked out though the initial coding process, inductive coding was used to identify common themes and patterns. By-subject coding interview data was examined and cases were constructed independently. That is, all of the
biology interviews was coded and a case built prior to moving on to data from chemistry or physics.

**Validity, Reliability, and Generalizability**

While the use of a validated research instrument that had been used to measure similar circumstances in other areas helped to build up the validity and reliability of this study, several threats to the validity and reliability of a study were inherent to conducting survey research. Calculating Cronbach’s alpha checked the validity of the instrument. Additionally, a pilot study of the survey was conducted. The fact that completing the survey was voluntary raises several issues.

It was impossible to ensure that a random sample of teachers would complete the survey. Time is a precious commodity for teachers and taking 15 to 20 minutes out of their day to complete the survey is a burden. As such, a teacher’s decision to complete the survey may be based on their views toward the NGSS and could influence the types of responses received from participants.

As the criteria for inclusion in this study are limited, the results of the study would only be generalizable [is dependent] to science teachers in NGSS states who identified as biology, chemistry, or physics teachers and were sent the survey. Teachers in states that have adapted, rather than adopted, the NGSS were excluded. Additionally, data from teachers who teach multiple content areas were also excluded.

**Protection of Human Subjects**

Based on the criteria provided by Frankel & Wallen (2009), it was likely that this study would fall under Category II (expedited review) in terms of IRB approval. This research study presented minimal ethical challenges and possible risks to research participants. Risks of
participation in this study were commensurate with normal daily activities. All survey data were confidential and no individual data was reported. In terms of the qualitative portion of this study, all data would again be confidential and only pseudonyms, where appropriate, were used in the reporting of this data. Participants were asked to consent to participation prior to beginning the survey and would given the option to provide an email address if they wished to participate in the qualitative phase. Additional participant consent would be obtained prior to this second phase of data collection.
Chapter 4: Results

Introduction

The purpose of this explanatory sequential mixed-methods study was to identify and compare the factors that influenced science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS, in the traditional disciplines of biology, chemistry, and physics. The central research question for this study was: What factors influence high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS? The sub-questions for this study were:

1. What factors contribute most to high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
2. What factors contribute most to high school biology teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
3. What factors contribute most to high school chemistry teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
4. What factors contribute most to high school physics teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
5. Why are the identified factors involved in receptivity an issue for biology, chemistry, and physics teachers respectively?
6. How do the identified factors operate in the classrooms and experiences of biology, chemistry, and physics teachers?
Quantitative Results

Quantitative Data Collection

The quantitative portion of this study utilized a survey that included a modified version of the Receptivity to Change instrument (Chi-Kin Lee, 2000) to gather data on teacher receptivity to the NGSS. The survey was conducted through the Qualtrics platform. Assistance in disseminating the survey was solicited from the National Science Teachers Association, the National Biology Teachers Association, the American Association of Chemistry Teachers, the American Association of Physics Teachers, state level science teacher organizations, and state departments of education. Only a handful of these organizations agreed to disseminate the survey through their listserv platform. These organizations are listed in Table 5.

It should be noted that while the National Association of Biology Teachers, the American Chemistry Teachers Association, the California Science Teachers Association, and the Rhode Island Science Teachers Association agreed to disseminate the survey, no responses from the survey links sent out by these organizations were obtained. Upon further investigation, it was discovered that the National Association of Biology Teachers and the Rhode Island Science Teachers Association did not distribute the survey request during the survey window. When the survey request was distributed by these organizations, it was embedded in their January 2018 monthly newsletter to their membership. No evidence that the American Chemistry Teachers Association or the California Science Teachers Association distributed the survey request were found.
Only the Nevada Science teachers association provided information on response rate. The survey was disseminated to their entire listserv [n = 468], which included non-high school science teachers. Their email had a click-through rate of 6.5% [n = 30] and a completion rate of 1.7% [n = 8].

Overall, the survey was responses for a month from November 6, 2017 to December 6, 2017. The survey was started by 489 participants and was completed by 76.3% [n = 373]. Descriptive statistics on level of survey completion are shown in Table 6. 105 completed surveys were from individuals in states that have not adopted the NGSS and were excluded from the final data set.
Quantitative Data Cleaning

At the conclusion of the survey period, the data from the survey were exported from the Qualtrics platform and loaded into SPSS. Data cleaning was accomplished through SPSS syntax coding and occurred in seven steps. To avoid introducing additional error, no data was cleaned manually.

The first step in data cleaning dealt with the three multiple response items in the survey, changing them into variables suitable for analysis. The next three steps in data cleaning involved deleting unused variables that were inserted by the Qualtrics program, renaming variables, relabeling variables, and correcting labeled variable measures in SPSS. The final step in data cleaning was the deletion of cases that were incomplete or from non-NGSS adopting states.

Sample Description

Data cleaning resulted in 286 valid cases for analysis. These cases represented individuals from 18 NGSS adopting states and the District of Columbia of the NGSS states, no complete responses were received from Vermont. Complete demographic information is shown in Table 7.

<table>
<thead>
<tr>
<th>Percent Complete</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>.00</td>
<td>1</td>
<td>.2</td>
<td>.2</td>
<td>.2</td>
</tr>
<tr>
<td>3.00</td>
<td>55</td>
<td>11.2</td>
<td>11.2</td>
<td>11.5</td>
</tr>
<tr>
<td>54.00</td>
<td>6</td>
<td>1.2</td>
<td>1.2</td>
<td>12.7</td>
</tr>
<tr>
<td>80.00</td>
<td>28</td>
<td>5.7</td>
<td>5.7</td>
<td>18.4</td>
</tr>
<tr>
<td>83.00</td>
<td>14</td>
<td>2.9</td>
<td>2.9</td>
<td>21.3</td>
</tr>
<tr>
<td>86.00</td>
<td>5</td>
<td>1.0</td>
<td>1.0</td>
<td>22.3</td>
</tr>
<tr>
<td>89.00</td>
<td>4</td>
<td>.8</td>
<td>.8</td>
<td>23.1</td>
</tr>
<tr>
<td>91.00</td>
<td>1</td>
<td>.2</td>
<td>.2</td>
<td>23.3</td>
</tr>
<tr>
<td>94.00</td>
<td>2</td>
<td>.4</td>
<td>.4</td>
<td>23.7</td>
</tr>
<tr>
<td>100.00</td>
<td>373</td>
<td>76.3</td>
<td>76.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>489</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Table 7

Demographic data for survey respondents.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>182</td>
<td>63.6</td>
</tr>
<tr>
<td>Male</td>
<td>104</td>
<td>36.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Highest Level of Education</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>High school</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Bachelors</td>
<td>54</td>
<td>18.9</td>
</tr>
<tr>
<td>Masters</td>
<td>209</td>
<td>73.1</td>
</tr>
<tr>
<td>Doctorate</td>
<td>21</td>
<td>7.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of Career</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 years</td>
<td>78</td>
<td>27.3</td>
</tr>
<tr>
<td>11-20 years</td>
<td>125</td>
<td>43.7</td>
</tr>
<tr>
<td>21-30+ years</td>
<td>83</td>
<td>29.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>School Type</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>251</td>
<td>87.8</td>
</tr>
<tr>
<td>Private</td>
<td>19</td>
<td>6.6</td>
</tr>
<tr>
<td>Charter</td>
<td>12</td>
<td>4.2</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject Taught</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>51</td>
<td>17.8</td>
</tr>
<tr>
<td>Chemistry</td>
<td>35</td>
<td>12.2</td>
</tr>
<tr>
<td>Physics</td>
<td>29</td>
<td>10.1</td>
</tr>
<tr>
<td>Other</td>
<td>25</td>
<td>8.7</td>
</tr>
<tr>
<td>Multiple</td>
<td>146</td>
<td>51.0</td>
</tr>
</tbody>
</table>

Several additional questions in the demographic portion of the survey gathered information on teachers’ professional development activities related to the NGSS, their self-rated knowledge of the NGSS, and their comparison of the workload of teaching to the NGSS as compared to their previous state standards. These results are shown in Table 8 below.

Table 8

NGSS specific data for survey respondents.

<table>
<thead>
<tr>
<th>Amount of NGSS Professional Development</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
</table>
None  8  2.8
1-5 hours  41  14.3
6-10 hours  40  14.0
11-15 hours  31  10.8
16-20 hours  28  9.8
21+ hours  138  48.3

<table>
<thead>
<tr>
<th>Self-rated knowledge of the NGSS</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not knowledgeable</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Slightly knowledgeable</td>
<td>46</td>
<td>16.1</td>
</tr>
<tr>
<td>Moderately knowledgeable</td>
<td>121</td>
<td>42.3</td>
</tr>
<tr>
<td>Significantly knowledgeable</td>
<td>118</td>
<td>41.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison of NGSS Workload to Previous Standards</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significantly more work</td>
<td>107</td>
<td>37.4</td>
</tr>
<tr>
<td>Slightly more work</td>
<td>87</td>
<td>30.4</td>
</tr>
<tr>
<td>Equal work</td>
<td>83</td>
<td>29.0</td>
</tr>
<tr>
<td>Slightly less</td>
<td>6</td>
<td>2.1</td>
</tr>
<tr>
<td>Significantly less</td>
<td>2</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Scale Development and Reliability Analysis**

Analysis of the factors involved in teacher receptivity to the NGSS involved the construction of six scales. Below outlines descriptions of the employed scales, their construction, Cronbach’s alpha, and how they were used in analysis.

**Receptivity: Dependent variable.** The receptivity scale was constructed by summing the nine items that required teachers to rank their feelings about the NGSS between two terms, with the middle position being neutral. For analysis purposes, this was set up like a seven point Likert scale, where the first term in each pair was assigned a value of one, the neutral position a value of four, and the last term a value of seven. The pairs of terms were: “satisfied to dissatisfied”, “not valuable to valuable”, “foolish to wise”, “restrictive to permissive”, “absurd to intelligent”, “impractical to practical”, “ineffective to effective”, “unnecessary to necessary”, and “complicated to uncomplicated”. A sample item can be found in Figure 3, and the full instrument can be found in Appendix B. The mean for this scale was 41.189 and the standard deviation was 13.551. Cronbach’s alpha for this scale was calculated to be 0.950.
Cost-benefit analysis: Independent variable. The cost-benefit scale was constructed by summing the seven survey items that corresponded to teachers’ cost-benefit analysis of the transition to the NGSS. These items were ranked on a seven-point Likert scale with strongly disagree assigned a value of one, neutral assigned a value of four, and strongly agree assigned a value of seven. The mean for this scale was 32.940 and the standard deviation was 9.959. Cronbach’s alpha for this scale was calculated to be 0.929. Item wording is shown in Table 9 and an item-level response breakdown is shown in Table 10. CoBe stands for “cost-benefit analysis”.

Table 9

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Item Wording</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoBe1</td>
<td>I think the NGSS are worthwhile when weighing the balance between the work they generate for me and my satisfaction with teaching.</td>
</tr>
<tr>
<td>CoBe2</td>
<td>I think the NGSS are worthwhile when weighing the balance between the work they generate for me and the changes in my teaching style it necessitates.</td>
</tr>
<tr>
<td>CoBe3</td>
<td>I think the NGSS are worthwhile when weighing the balance between the work they generate for me and improvement in student learning.</td>
</tr>
<tr>
<td>CoBe4</td>
<td>I think the NGSS are worthwhile when weighing the balance between the work they generate for me and the increased commitment towards improving science literacy by the students.</td>
</tr>
<tr>
<td>CoBe5</td>
<td>I think the NGSS are worthwhile when weighing the balance between the work they generate for me and praise by my school principal.</td>
</tr>
<tr>
<td>CoBe6</td>
<td>I think the NGSS are worthwhile when weighing the balance between the work they generate for me and better student engagement with science concepts and skills.</td>
</tr>
<tr>
<td>CoBe7</td>
<td>I think the NGSS are worthwhile when weighing the balance between the work they generate for me and improvement in my professional status as a teacher.</td>
</tr>
</tbody>
</table>

Table 10

Frequency table for the cost-benefit analysis survey items.
Perceived practicality: Independent variable. The perceived practicality scale was constructed by summing the five survey items that corresponded to teachers’ perceptions of the practicality of transitioning to the NGSS. These items were ranked on a seven point Likert scale, with strongly disagree assigned a value of one, neutral assigned a value of four, and strongly agree assigned a value of seven. The mean for this scale was 26.751 and the standard deviation was 6.102. Cronbach’s alpha for this scale was calculated to be 0.893. Item wording is shown in Table 11 and an item-level response breakdown is shown in Table 12. PePrc stands for “perceived practicality.”
The principles of three dimensional learning that are integral to the NGSS and suggested by the Framework for K-12 Science Education suit my classroom teaching style.

The NGSS practice of engaging in argument from evidence reflects my educational philosophy.

The principle of encouraging the individual student’s contribution and participation suggested by the NGSS is likely to be realized in my classroom context.

The principles of implementing the NGSS through both the formal and informal curriculum are appropriate to meeting the needs of the students in my school.

The principle of supporting ideas with empirical evidence included in the NGSS matches my knowledge and skills in teaching science.

Table 12

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>PePrc1</td>
<td>9 (3.1%)</td>
<td>17 (5.9%)</td>
<td>22 (7.7%)</td>
<td>25 (8.7%)</td>
<td>67 (23.4%)</td>
<td>90 (31.5%)</td>
<td>56 (19.6%)</td>
</tr>
<tr>
<td>PePrc2</td>
<td>5 (1.7%)</td>
<td>6 (2.1%)</td>
<td>14 (4.9%)</td>
<td>29 (10.1%)</td>
<td>47 (16.4%)</td>
<td>96 (33.6%)</td>
<td>89 (31.1%)</td>
</tr>
<tr>
<td>PePrc3</td>
<td>6 (2.1%)</td>
<td>8 (2.8%)</td>
<td>22 (7.7%)</td>
<td>33 (11.5%)</td>
<td>64 (22.4%)</td>
<td>98 (34.3%)</td>
<td>55 (19.2%)</td>
</tr>
<tr>
<td>PePrc4</td>
<td>7 (2.4%)</td>
<td>17 (5.9%)</td>
<td>28 (9.8%)</td>
<td>49 (17.1%)</td>
<td>60 (21.0%)</td>
<td>73 (25.5%)</td>
<td>50 (17.5%)</td>
</tr>
<tr>
<td>PePrc5</td>
<td>3 (1.0%)</td>
<td>6 (2.1%)</td>
<td>8 (2.8%)</td>
<td>23 (8.0%)</td>
<td>64 (22.4%)</td>
<td>81 (28.3%)</td>
<td>101 (35.3%)</td>
</tr>
</tbody>
</table>

Note: Two responses (0.7%) were missing for PerPrc 4.

**Issues of concern: Independent variable.** The issues of concern scale was constructed by summing the six survey items that corresponded to teachers’ perceptions of issues of concern in the transition to the NGSS. These items were ranked on a seven point Likert scale with strongly disagree assigned a value of one, neutral assigned a value of four, and strongly agree assigned a value of seven. Cronbach’s alpha for this raw scale was calculated to be 0.693.

Analysis of the effect that removing an item from the scale would have on Cronbach’s alpha identified item Con2 as problematic. Con2 was removed and this created a modified scale, labeled as ConMod, which contained five items. The mean for this scale was 19.965 and the
standard deviation was 6.442. The ConMod scale had a Cronbach’s alpha of 0.733. Item wording for the items used to calculate ConRaw and ConMod are shown in Table 13 and an item-level response breakdown is shown in Table 14. Con stands for “issues of concern”.

Table 13

Issues of concern item wording.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Item Wording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Con1</td>
<td>I am concerned that students have incorrect attitudes towards science and engineering.</td>
</tr>
<tr>
<td>Con2</td>
<td>I am concerned that English language arts and mathematics receive more attention than other subjects.</td>
</tr>
<tr>
<td>Con3</td>
<td>I am concerned that the introduction of the NGSS will result in lower academic performance among the students at my school.</td>
</tr>
<tr>
<td>Con4</td>
<td>I am concerned that the introduction of NGSS will lead to less time being available for the teaching of the content in my subject.</td>
</tr>
<tr>
<td>Con5</td>
<td>The students’ abilities are causing me concern in regard to the teaching of NGSS at my school.</td>
</tr>
<tr>
<td>Con6</td>
<td>Disciplinary problems are causing me concern in regard to the teaching of NGSS at my school.</td>
</tr>
</tbody>
</table>

Table 14

Frequency table for the issues of concern survey items.

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Con1</td>
<td>5</td>
<td>12</td>
<td>20</td>
<td>36</td>
<td>88</td>
<td>77</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>(1.7%)</td>
<td>(4.2%)</td>
<td>(7.0%)</td>
<td>(12.6%)</td>
<td>(30.8%)</td>
<td>(26.9%)</td>
<td>(16.8%)</td>
</tr>
<tr>
<td>Con2</td>
<td>8</td>
<td>19</td>
<td>17</td>
<td>35</td>
<td>51</td>
<td>68</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>(2.8%)</td>
<td>(6.6%)</td>
<td>(5.9%)</td>
<td>(12.2%)</td>
<td>(17.8%)</td>
<td>(23.8%)</td>
<td>(30.8%)</td>
</tr>
<tr>
<td>Con3</td>
<td>53</td>
<td>66</td>
<td>35</td>
<td>42</td>
<td>43</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>(18.5%)</td>
<td>(23.1%)</td>
<td>(12.2%)</td>
<td>(14.7%)</td>
<td>(15.0%)</td>
<td>(9.8%)</td>
<td>(6.6%)</td>
</tr>
<tr>
<td>Con4</td>
<td>46</td>
<td>55</td>
<td>32</td>
<td>37</td>
<td>43</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>(16.1%)</td>
<td>(19.2%)</td>
<td>(11.2%)</td>
<td>(12.9%)</td>
<td>(15.0%)</td>
<td>(13.3%)</td>
<td>(12.2%)</td>
</tr>
<tr>
<td>Con5</td>
<td>36</td>
<td>39</td>
<td>19</td>
<td>42</td>
<td>72</td>
<td>48</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>(12.6%)</td>
<td>(13.6%)</td>
<td>(6.6%)</td>
<td>(14.7%)</td>
<td>(25.2%)</td>
<td>(46.8%)</td>
<td>(10.5%)</td>
</tr>
<tr>
<td>Con6</td>
<td>71</td>
<td>52</td>
<td>15</td>
<td>53</td>
<td>47</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>(24.8%)</td>
<td>(18.2%)</td>
<td>(5.2%)</td>
<td>(18.5%)</td>
<td>(16.4%)</td>
<td>(8.0%)</td>
<td>(8.7%)</td>
</tr>
</tbody>
</table>

School support: Independent variable. The school support scale was constructed by summing the seven survey items that corresponded to participants’ view of school-based support for transitioning to the NGSS. These items were ranked on a seven point Likert scale with
strongly disagree assigned a value of one, neutral assigned a value of four, and strongly agree assigned a value of seven. The mean for this scale was 23.668 and the standard deviation was 9.384. Cronbach’s alpha for this scale was calculated to be 0.837. Item wording is shown in Table 15 and an item-level response breakdown is shown in Table 16. ScSup stands for school-based support.

Table 15

*School support item wording.*

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Item Wording</th>
</tr>
</thead>
<tbody>
<tr>
<td>ScSup1</td>
<td>There are regular meetings at which I can raise my worries and doubts about the implementation of NGSS.</td>
</tr>
<tr>
<td>ScSup2</td>
<td>Whenever there are problems implementing NGSS, there is a senior teacher whom I can ask for advice.</td>
</tr>
<tr>
<td>ScSup3</td>
<td>There is good support whenever I have problems, such as a shortage of books and equipment, related to NGSS.</td>
</tr>
<tr>
<td>ScSup4</td>
<td>There are regular school-based professional development programs at which I can learn how to teach to the NGSS.</td>
</tr>
<tr>
<td>ScSup5</td>
<td>The majority of teachers in my school support the NGSS.</td>
</tr>
<tr>
<td>ScSup6</td>
<td>The principal encourages teachers to participate in training courses related to the NGSS.</td>
</tr>
<tr>
<td>ScSup7</td>
<td>At school meetings, the principal makes comments emphasizing the importance of introducing NGSS at my school.</td>
</tr>
</tbody>
</table>

Table 16

*Frequency table for the school support survey items.*

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>ScSup1</td>
<td>76 (26.6%)</td>
<td>56 (19.6%)</td>
<td>36 (12.6%)</td>
<td>21 (7.3%)</td>
<td>52 (18.2%)</td>
<td>30 (10.5%)</td>
<td>15 (5.2%)</td>
</tr>
</tbody>
</table>
Other support: Independent variable. The other support scale was constructed by summing the five survey items that corresponded to participant’s view of non-school based support for transitioning to the NGSS. These items were ranked on a seven point Likert scale with strongly disagree assigned a value of one, neutral assigned a value of four, and strongly agree assigned a value of seven. The mean for this scale was 18.444 and the standard deviation was 5.472. Cronbach’s alpha for this scale was calculated to be 0.765. Item wording is shown in Table 17 and an item-level response breakdown is shown in Table 18. OtSup stands for “other support” not located within the school.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Item Wording</th>
</tr>
</thead>
<tbody>
<tr>
<td>OtSup1</td>
<td>In my opinion, the United States Department of Education supports the implementation of NGSS in my school.</td>
</tr>
<tr>
<td>OtSup2</td>
<td>In my opinion, the state department of education provides sufficient suggestions and assistance to help teachers acquire the methods of implementing NGSS in my school.</td>
</tr>
</tbody>
</table>
In my opinion, the science teacher organizations provide adequate support for promoting NGSS in my school.

In my opinion, the majority of parents in this school support the implementation of NGSS in my school.

In my opinion, the local community organizations provide adequate community resources for student participation.

Table 18

*Frequency table for the other support survey items.*

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>OtSup1</td>
<td>33 (11.5%)</td>
<td>44 (15.4%)</td>
<td>33 (11.5%)</td>
<td>89 (31.1%)</td>
<td>49 (17.1%)</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>OtSup2</td>
<td>54 (18.9%)</td>
<td>59 (20.6%)</td>
<td>46 (16.1%)</td>
<td>46 (16.1%)</td>
<td>49 (17.1%)</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>OtSup3</td>
<td>8 (2.8%)</td>
<td>26 (9.1%)</td>
<td>27 (9.4%)</td>
<td>37 (12.9%)</td>
<td>92 (32.2%)</td>
<td>64</td>
<td>32</td>
</tr>
<tr>
<td>OtSup4</td>
<td>28 (9.8%)</td>
<td>38 (13.3%)</td>
<td>36 (12.6%)</td>
<td>144 (50.3%)</td>
<td>25 (8.7%)</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>OtSup5</td>
<td>47 (16.4%)</td>
<td>56 (19.6%)</td>
<td>38 (13.3%)</td>
<td>105 (36.7%)</td>
<td>24 (8.4%)</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: One response (0.3%) was missing for OtSup5.

**Holistic Model**

What factors contributed most to high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS? To answer this question, a univariate general linear model, shown in Table 19, was constructed with the receptivity scale as the dependent variable and 16 predictor variables.

The predictor, or independent, variables could be divided into two main categories: demographic predictors and scale predictors. Demographic predictors included length of teaching career [YRS], certification [CertBioChemPhys], professional memberships [Memberships], subject taught [BioChemPhys], school location [SchLoc], school type [SchTyp], amount of NGSS professional development [PDTime], self-rated knowledge of the NGSS [NGSSKNOW], self-rated comparison of the workload of the NGSS to previous standards.
[NGSSWKLD], gender [Gender], and highest level of education [EDUH]. The scale predictors, constructed from the survey items, included were cost-benefit analysis [CostBenefitRaw], perceived practicality [PerPracRaw], issues of concern [ConMod], school support [ScSupRaw], and other support [OtSupRaw].

This model had an $R^2$ of 0.76 (adjusted $R^2 = 0.720$), which showed that 76.0% of the variance could be explained by the predictors. An $R^2$ of 0.760 indicated a strong fit. The F value for the model is 18.795 and the model itself had a $p$ of 0.000. This model was presented as the following formula: receptivity = 5.281 + 116.341(cost-benefit) + 10.390(issues of concern) + 3.953(perceived practicality) + 1.318(school support) + 0.120(other support) + 2.161(career length) + 0.466(certification) + 0.727(professional memberships) + 1.413(subject taught) + 1.646(school location) + 1.240(school type) + 0.884(professional development) + 0.679(knowledge of the NGSS) + 1.962(view of NGSS workload) + 1.331(gender) + 1.939(level of education).

The model showed that three factors were statistically significant at the $p = 0.05$ level. Factors included cost-benefit analysis, perceived practicality, and issues of concern. None of the other predictors were statistically significant. Further, given the high coefficient attached to cost-benefit analysis, it was clear that this factor drove the model and exerted the greatest influence on teacher receptivity to the NGSS.

Table 19

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>39772.729$^a$</td>
<td>41</td>
<td>970.067</td>
<td>18.795</td>
<td>.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>272.582</td>
<td>1</td>
<td>272.582</td>
<td>5.281</td>
<td>.022</td>
</tr>
<tr>
<td>CostBenefitRaw</td>
<td>6004.670</td>
<td>1</td>
<td>6004.670</td>
<td>116.341</td>
<td>.000</td>
</tr>
<tr>
<td>PerPracRaw</td>
<td>204.034</td>
<td>1</td>
<td>204.034</td>
<td>3.953</td>
<td>.048</td>
</tr>
<tr>
<td>ConMod</td>
<td>536.267</td>
<td>1</td>
<td>536.267</td>
<td>10.390</td>
<td>.001</td>
</tr>
</tbody>
</table>
In order to investigate the factors involved in receptivity in greater detail, a second multiple linear regression model was constructed using receptivity as the dependent variable and the items in cost-benefit scale, the perceived practicality scale, and the issues of concern scale as predictors. Demographic predictors and the other non-significant scale predictors were excluded.

The results of this analysis are shown in Table 20. This model had an $R^2$ 0.763, indicating a strong fit. The F test for this model was 50.44 and $p$ for the model was less than 0.0005.

Table 20

<table>
<thead>
<tr>
<th>Holistic Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>(Constant)</td>
</tr>
<tr>
<td>CoBe1</td>
</tr>
<tr>
<td>CoBe2</td>
</tr>
<tr>
<td>CoBe3</td>
</tr>
<tr>
<td>CoBe4</td>
</tr>
<tr>
<td>CoBe5</td>
</tr>
<tr>
<td>CoBe6</td>
</tr>
<tr>
<td>CoBe7</td>
</tr>
<tr>
<td>PePrc1</td>
</tr>
</tbody>
</table>
Investigation of the individual predictors was undertaken to better understand the drivers of receptivity. It was important to first note that though some of the tolerance levels were low, none violated the convention of less than 0.1. At this stage, research moved into a type of exploratory post hoc analysis. An argument could be made for the need to address type I error rates by adjusting $\alpha$. In this case, the Bonferroni adjustment was calculated by dividing $\alpha$ by the number of further ‘tests’ [intentionally not called pairwise comparisons]. Thus $\alpha = \frac{.05}{17} = .0029$.

Using the Bonferroni adjustment, three items in the model showed a statistically significant linear relationship with receptivity to the NGSS. These were CoBe1, CoBe4, and PePrc4.

CoBe1 addressed cost-benefit analysis in relation to satisfaction with teaching. $\beta$ for CoBe1 was 0.195, indicating that for every one unit of increase in the item, receptivity increased by 0.195. Since $\beta$ was positive, there was a positive relationship between this item and receptivity. Further, the partial correlation for CoBe1 was 0.197. The tolerance for CoBe1 was 0.249.

CoBe1 required the respondent to weigh the added work of teaching to the NGSS against their satisfaction with teaching to make a determination if, in their view, the standards were worthwhile. As CoBe1 increased by one unit, receptivity increased by 0.195. For those with a

<table>
<thead>
<tr>
<th></th>
<th>PePrc2</th>
<th>PePrc3</th>
<th>PePrc4</th>
<th>PePrc5</th>
<th>Con1</th>
<th>Con3</th>
<th>Con4</th>
<th>Con5</th>
<th>Con6</th>
</tr>
</thead>
<tbody>
<tr>
<td>.572</td>
<td>.466</td>
<td>.059</td>
<td>1.226</td>
<td>.221</td>
<td>.558</td>
<td>.075</td>
<td>.037</td>
<td>.383</td>
<td>2.610</td>
</tr>
<tr>
<td>-.840</td>
<td>.476</td>
<td>-.089</td>
<td>-1.763</td>
<td>.079</td>
<td>.581</td>
<td>-.107</td>
<td>-.053</td>
<td>.353</td>
<td>2.833</td>
</tr>
<tr>
<td>1.632</td>
<td>.431</td>
<td>.189</td>
<td>3.787</td>
<td>.000</td>
<td>.689</td>
<td>.226</td>
<td>.113</td>
<td>.358</td>
<td>2.794</td>
</tr>
<tr>
<td>.287</td>
<td>.498</td>
<td>.028</td>
<td>.577</td>
<td>.564</td>
<td>.548</td>
<td>.035</td>
<td>.017</td>
<td>.391</td>
<td>2.559</td>
</tr>
<tr>
<td>.248</td>
<td>.320</td>
<td>.026</td>
<td>.775</td>
<td>.439</td>
<td>.209</td>
<td>.047</td>
<td>.023</td>
<td>.802</td>
<td>1.247</td>
</tr>
<tr>
<td>-.003</td>
<td>.334</td>
<td>.000</td>
<td>-.010</td>
<td>.992</td>
<td>-.477</td>
<td>-.001</td>
<td>.000</td>
<td>.424</td>
<td>2.360</td>
</tr>
<tr>
<td>-.852</td>
<td>.311</td>
<td>-.127</td>
<td>-2.736</td>
<td>.007</td>
<td>-.573</td>
<td>-.165</td>
<td>-.082</td>
<td>.415</td>
<td>2.407</td>
</tr>
<tr>
<td>-.357</td>
<td>.318</td>
<td>-.050</td>
<td>-.1125</td>
<td>.262</td>
<td>-.336</td>
<td>-.069</td>
<td>-.034</td>
<td>.455</td>
<td>2.200</td>
</tr>
<tr>
<td>-.061</td>
<td>.269</td>
<td>-.009</td>
<td>-.228</td>
<td>.820</td>
<td>-.273</td>
<td>-.014</td>
<td>-.007</td>
<td>.570</td>
<td>1.753</td>
</tr>
</tbody>
</table>

Note: Con2 omitted
negative response, “strongly disagree” to “somewhat disagree”, this meant that the increased work of the NGSS decreased their satisfaction with teaching and this decreased receptivity to the standards. Conversely positive responses, “somewhat agree” to “strongly agree”, were associated with higher receptivity. The work generated by changing to the standards included making changes to curriculum, redesigning instruction, and changing teaching methodology. A scatter plot of responses to this item and receptivity is shown in Figure 4.

Figure 4. CoBe1 scatter plot.
CoBe4 addressed cost-benefit analysis in relation to improved science literacy among students. $\beta$ for CoBe4 is 0.229, indicated that for every one unit of increase in the item, receptivity increased by 0.229. As in CoBe1, $\beta$ for this predictor variable was positive which indicated a positive relationship between this variable and receptivity. The partial correlation for CoBe4 was 0.226 and the tolerance for CoBe4 was 0.244.

CoBe4 required the respondent to weigh the added work of teaching to the NGSS against improvements in students’ science literacy to make a determination if, in their view, the standards were worthwhile. For those with a negative response, “strongly disagree” to “somewhat disagree”, this meant that the increased work of the NGSS was not offset by their view of the power of the NGSS to increased science literacy and this decreased receptivity to the standards. Conversely positive responses, “somewhat agree” to “strongly agree”, were associated
with higher receptivity. A scatter plot of responses to this item and receptivity is shown in Figure 5.

*Figure 5. CoBe4 scatter plot.*

PePrC4 addressed the appropriateness of the NGSS for the students in a teacher’s school. β for PePrC4 was 0.189, indicating that for every one unit of increase in the item, receptivity increased by 0.189. As in the significant cost-benefit predictors, β for this predictor variable was positive which indicated a positive relationship between this variable and receptivity. The partial correlation for PePrC4 was 0.113. The tolerance for PePrC4 was 0.358. Perspectives on the appropriateness of the NGSS for students could take a variety of forms. For example, students may be inadequately prepared for the inquiry-based nature of the NGSS or may not have the
ability to behave appropriately in a lab-based collaborative learning setting. Appropriateness of the standards for students could also be questioned by teachers of students at the higher end of the academic spectrum, as the NGSS removed much of the challenging, math-based content from high school science. A scatter plot of responses to this item and receptivity is shown in Figure 6.

Figure 6. PePrc4 scatter plot.

Subject Specific Models

Research questions two through four focused on factors involved in receptivity for teachers of the three different high school science subjects that were traditionally taught in American high schools. This section described the linear regression models constructed to identify the significant factors involved in receptivity for biology, chemistry, and physics.
teachers. It was important to note that the subject taught by a teacher [BioChemPhys] was not a statistically significant predictor of receptivity in the holistic model. Table 21 shows the number of pure biology, chemistry and physics teachers used for the following analyses. These teachers did not teach another core subject area.

Table 21

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>Biology</td>
<td>51</td>
<td>44.3</td>
<td>44.3</td>
</tr>
<tr>
<td></td>
<td>Chemistry</td>
<td>35</td>
<td>30.4</td>
<td>74.8</td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>29</td>
<td>25.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>115</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Biology.** The second research question examined the factors that influenced high school biology teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS. A multiple linear regression model of biology teachers was constructed using the five scale items. This model, shown in Table 22, had an adjusted $R^2$ of 0.730, indicating a strong fit. The F test for this model was 24.285 and $p$ for the model was 0.000. Only one of the factors in the model, CostBenefitRaw, was statistically significant at the $p = 0.05$ level.

Table 22

**Biology Model**
The third research question examined the factors that influenced high school chemistry teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS. A multiple linear regression model for chemistry teachers was constructed using the five scale items. This model, shown in Table 23, had a $R^2$ of 0.515, indicating a moderate fit. The F test for this model was 6.152 and $p$ for the model was 0.001. As in the biology model, only one of the factors in the model, CostBenefitRaw, was statistically significant at the $p = 0.05$ level.

Table 23

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$B$</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>12.377</td>
<td>13.743</td>
</tr>
<tr>
<td></td>
<td>CostBenefitRaw</td>
<td>.869</td>
<td>.310</td>
</tr>
<tr>
<td></td>
<td>PerPracRaw</td>
<td>.339</td>
<td>.466</td>
</tr>
<tr>
<td></td>
<td>ConMod</td>
<td>-.241</td>
<td>.329</td>
</tr>
<tr>
<td></td>
<td>ScSupRaw</td>
<td>-.068</td>
<td>.260</td>
</tr>
<tr>
<td></td>
<td>OtSupRaw</td>
<td>.025</td>
<td>.452</td>
</tr>
</tbody>
</table>

a. Dependent Variable: ReceptivityRaw
b. Selecting only cases for which were recoded to reflect only bio, chemistry, physics other, or multiple = Chemistry

The fourth research question examined the factors that influenced high school physics teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS. A
multiple linear regression model for physics teachers was constructed using the five scale items. This model, shown in Table 24, had an $R^2$ of 0.645, indicating a strong fit. The $F$ test for this model was 8.357 and $p$ for the model was 0.000. Again, only one of the factors in the model, CostBenefitRaw, was statistically significant at the $p = 0.05$ level.

Table 24

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$B$</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>(Constant)</td>
<td>-2.874</td>
<td>15.815</td>
<td>-.182</td>
</tr>
<tr>
<td>CostBenefitRaw</td>
<td>1.274</td>
<td>.288</td>
<td>.795</td>
</tr>
<tr>
<td>PerPracRaw</td>
<td>.156</td>
<td>.377</td>
<td>.066</td>
</tr>
<tr>
<td>ConMod</td>
<td>-.021</td>
<td>.368</td>
<td>-.008</td>
</tr>
<tr>
<td>ScSupRaw</td>
<td>.309</td>
<td>.285</td>
<td>.154</td>
</tr>
<tr>
<td>OtSupRaw</td>
<td>-.365</td>
<td>.576</td>
<td>-.106</td>
</tr>
</tbody>
</table>

*a. Dependent Variable: ReceptivityRaw
b. Selecting only cases for which were recoded to reflect only bio chem physics other, or multiple = Physics

Conclusion

Based on the quantitative analysis, three factors were significant in terms of high school science teachers’ receptivity to the shifts in teaching and learning necessitated by the adoption of the NGSS. These factors were teachers’ non-monetary cost benefit analysis, perceptions of the practicality of implementing the standards, and issues of concern.

Identification of the three significant factors in the holistic model prompted the construction of a second model which used the individual items in the survey as predictors. This analysis allowed for the specific factors within those scales that influenced receptivity to be isolated. Teachers’ cost-benefit analysis hinged on the work created by teaching to the NGSS, their satisfaction with teaching and their views on the NGSS’s improvement in science literacy among students, and their students engagement in science under the NGSS. Teachers
perceived practicality in implementing the standards focused on their view of the NGSS as meeting the curricular needs of their students.

**Qualitative Results**

**Qualitative Data Collection and Management**

The initial qualitative data collection plan for this study proposed the construction of three multiple embedded case studies, one for each of the domains. This idea was predicated on the presumption that subject area would be a statistically significant predictor of receptivity. The quantitative results of this study showed that biology, chemistry, and physics teachers did not have statistically significant differences in their receptivity. Further, the analysis of the subject specific models showed that the same factor, cost-benefit analysis, was the most significant predictor of receptivity for all domains. These findings resulted in an adjustment to the planned qualitative data collection and analysis. Instead of constructing subject-specific cases, a detailed qualitative analysis of each significant factor was undertaken.

Following the conclusion of the quantitative data collection period, cases were selected from the data set for follow-up interviews. These teachers indicated within the survey that they were interested in completing a follow-up interview. In total, 24 teachers, six from each subject area [biology, chemistry, physics, and multiple subjects] were contacted for follow-up. Of that group, 12 agreed to participate after being contacted. These are listed in Table 25. Teachers with receptivity scores less than 36 were identified as resistant and teachers with scores above 36 were identified as receptive, 36 was the midpoint of the receptivity scale. Interviews were recorded and transcribed using the Rev.com app.

Table 25

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Subject</th>
<th>Receptivity</th>
</tr>
</thead>
</table>

*Interview Participants*
**Coding.** Creswell (2009) defines coding as the process of making sense out of the data by using codes that describe a segment of data. Coding for this study was accomplished in two phases. In phase one, *a priori* codes generated from the survey were used to identify relevant data. These codes are shown in Table 26. In phase two, inductive coding was used to identify themes within related chunks of data.

Table 26

<table>
<thead>
<tr>
<th>A priori codes.</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative Scale</td>
<td></td>
</tr>
<tr>
<td>Cost-benefit analysis</td>
<td>cost, benefit, time, science literacy, college, career</td>
</tr>
<tr>
<td>Perceived practicality</td>
<td>practicality, teaching style, pedagogy, practices of science</td>
</tr>
<tr>
<td>Issues of concern</td>
<td>concern, attitude, ability, behavior, preparation</td>
</tr>
</tbody>
</table>

**Qualitative Results**

The quantitative model identified three factors as statistically significant predictors of teacher receptivity: non-monetary cost-benefit analysis, perceived practicality, and issues of concern. This section described the qualitative findings obtained from the interview participants about these factors. The qualitative research questions for this study were: (1) Why are the identified factors involved in receptivity an issue for biology, chemistry, and physics teachers?
respectively? and (2) How do the identified factors operate in the classrooms and experiences of biology, chemistry, and physics teachers?

**Non-monetary cost-benefit analysis.** Non-monetary cost-benefit analysis was the strongest predictor of receptivity identified by the holistic model and the only statistically significant predictor of receptivity in the subject-specific models. Across all of the domains, two major themes related to teachers’ non-monetary cost-benefit analysis were identified: costs and benefits.

**Costs.** Coding of the interview transcripts identified time as a significant non-monetary cost that teachers saw as influencing their receptivity to the NGSS. Both receptive and non-receptive teachers reported that adapting lessons to the NGSS was a significant “cost” in terms of time. Kristen, a receptive, multi-subject. science teacher captured this with the most clarity:

I think it's a lot of work as far as switching your curriculum to NGSS because I kind of did the traditional give notes, we would do cookbook type labs, and I think that's pretty standard for most teachers. But doing the NGSS, to switch your curriculum to that, is just a whole new mindset... You really have to kind of give up everything you did before.

(Kristen, Interview Transcript, December 14, 2017)

Time estimates for revising lessons to the NGSS varied considerably, from 10 minutes for a resistant teacher who decided he would only select the relevant standards in his school’s virtual lesson plan program without modifying any lessons, to an entire week to modify a single lesson. Similarly, estimates on the number of lessons that needed to be revised ranged from zero, for one highly resistant teacher, to all of them, for one highly receptive teacher.

For the teachers interviewed, the time required for lesson revision or development was often not provided by the school. Instead, teachers were expected to work on development of
curriculum and instruction on their own time. Timothy, a resistant physics teacher, bluntly stated this problem:

There's a lot of time involved in preparing a true NGSS lesson. I'm going to be quite honest and say that I am nowhere near where I need to be for NGSS… for me the big cost to me is time. I'm a father of four young children, I just don't have the time to develop everything that it needs to convert my whole regime over to NGSS. I'm just not there yet. You still have to teach all five courses and you still have all the classes in a full day but truly moving to an NGSS is going to require a lot of time. (Timothy, Interview Transcript, December 14, 2017)

Additionally, teachers also discussed the time period under which alignment of lessons to the NGSS needed to occur. For teachers who intended to make changes to their curriculum, all identified this as a multi-year project. Rapid transition to the NGSS did not appear to be feasible from the perspective of these teachers.

**Benefits.** While the teachers universally agreed, regardless of receptivity about the time related costs of the NGSS, they disagreed on the benefits. The NGSS document itself explicitly stated that the standards were designed to increase college and career readiness. Among the 12 participants in the qualitative portion of this study, there was greater agreement about the potential of the standards to increase career readiness than college readiness.

All receptive and several resistant participants discussed career readiness in terms of both the skills imparted by the NGSS and the connections to careers that would be highlighted for students. Career skills included problem solving, dealing with uncertainty and failure, working collaboratively, and engaging in argument from evidence. Monica, a receptive physics teacher said “not every kid you teach is going to be an engineer or scientist. I think NGSS does keep that
in mind that kids can develop skills they can use in any career” (Monica, Interview Transcript, December 14, 2017). Career connections to clean energy and environmental science were also included by a few participants. Non-explicit career connections included generating excitement about science and technology.

Two, non-receptive teachers saw no benefits in terms of career readiness. Joshua, a non-receptive biology teacher shared “I don't see it having any impact on their career, especially if the kid is going to be [a] tailor or a bell hop in a hotel, I'd argue scientific principles aren’t gonna help them in the slightest” (Joshua, Interview Transcript, December 12, 2017).

Teachers’ opinions on the effect of the NGSS on college readiness were mixed. College readiness was broken down by many of the participants into two categories, preparation for college-level coursework in non-science areas and preparation for college-level science coursework. Teachers, both receptive and non-receptive, expressed that the NGSS does a far better job of preparing students for coursework that was outside of the scientific disciplines. Many of the skills identified in career readiness, such as collaborative work and engaging in argument from evidence, were also highlighted as reasons why the NGSS would improve college readiness.

Preparation for college-level, science coursework was discussed from a content and laboratory perspective. Most of the participants, both receptive and non-receptive, expressed that the inquiry focus of the NGSS would help students be more prepared for the laboratory portion of their college-level science coursework. On the other hand, when discussing preparation for college-level science content, participants who were receptive and non-receptive expressed doubts. Alice, a receptive physics teacher stated:
I think they would be very prepared to take other [non-science] courses in college. I think they would be prepared to write those papers and to answer those questions and to think critically. As far as the contents, like specificity, I don't think they'd be ready. Does that make sense? I think the gap is in the math portion of it. Again, the emphasis that we, in our district, have seen placed on the reasoning seems to have diminished the importance of the answer. Especially in hard [subjects] like Chemistry and Physics, where there is an answer. It either is or it isn't, and then you have to explain why. (Alice, Interview Transcript, December 14, 2017).

Timothy, a resistant multi-subject teacher, highlighted this tension most succinctly:

I'm a little bit worried that these kids are going to get to college and they're going to take their first introduction to physics course and I don't think they're not going to have the foundation. It's going to be tough in college. I don't see college moving the way of NGSS, so we're changing but is the university level changing? (Timothy, Interview Transcript, December 15, 2017).

**Non-monetary cost-benefit analysis: A summary.** Non-monetary cost-benefit analysis was the strongest predictor of teacher receptivity in the holistic model and the only predictor of receptivity in the subject-specific models. Across all interview participants, regardless of subject or receptivity level, time was seen as the most significant non-monetary cost to teachers. Whether the costs outweighed the benefits differed among teachers. Benefits of transitioning to the NGSS were broken down into career readiness, non-science college readiness, and college science readiness. Consensus among the teachers as to the benefits of transitioning to the NGSS was strongest for career readiness and weakest for college science readiness.
Perceived practicality. Perceived practicality was only identified as a significant predictor by the holistic model. Across all of the domains, three major themes related to teachers’ perceptions about the practicality of the NGSS emerged. These barriers to implementation were state testing, the lack of concrete examples of NGSS-aligned instruction, and problems with accessing high-quality professional development.

State testing. Similar to the issue of time identified in the non-monetary cost-benefit analysis factor, state testing was a factor that came up among teachers of all levels of receptivity. Participants in the follow-up interviews represented several NGSS states at various stages of implementation and with large differences in their state’s testing structure. As such, issues related to state testing differed among participants. In some states, like Michigan, the continued presence of the state science test that was not aligned to the NGSS impacted teachers’ perceptions of the practicality of the NGSS. This was a legitimate concern. If they changed their curriculum to focus on the NGSS, their students would then be prepared for the state test.

In other states, the testing timeframe, such as testing at the end of sophomore year when students have not been exposed to all of the content, was seen as a problem. The NGSS standards were designed to be taught over a period of three years. Appendix K in the NGSS standards document identified three pathways through the standards, all designed to be done over a three-year period.

Lack of concrete examples of NGSS-aligned instruction. Several resistant teachers raised a concern about the lack of concrete examples of what NGSS-aligned instruction looked like. Jameson, a resistant physics teacher provided the most cohesive statement about this issue:

The people who present it [the NGSS] they give you general ways of implementing this stuff or very small vignettes but they never show you how to make it. They don't do the
example. Show us a lesson. Maybe a series of lessons that covers the content that needs to be covered in the way that you want it covered. Show how you measure your success in it and have some consistency over some time to do this program.

The lack of examples of what NGSS aligned instruction looked like went beyond just examples from professional development. One participant, Timothy, pointed out that the major publication companies had not yet caught up to the NGSS across all domains. According to Timothy, more NGSS materials were available for biology than for other content areas.

**Accessing professional development.** Professional development (PD) varied in quality and availability. Most of the participants in the interview portion of the study had attended some form of PD on the standards. PD was provided at different levels and varied in cost. Some participants only received professional development within their local school district, while most others received it from an outside source. Outside sources included representatives from state departments of education, regional science teacher institutes, NSTA, or other organizations.

Three teachers, Monica, Kristen, and Vincent, attended intensive NGSS professional development programs in the summer. Monica, a receptive physics teacher, and Kristen, a receptive multi-subject teacher, were able to attend the NGSX training. Vincent, attended a two-week Modeling Instruction PD.

Both the NGSX training and Modeling Instruction was intensive professional development programs that took place for one to two weeks during the summer. They were not easily accessible, in that they often required teachers to travel and were expensive. In this sample, the teachers that attended the NGSX or Modeling Instruction professional development programs were the only members of their department to attend the trainings, which made taking
what they learned back to their schools difficult. The following quote from Kristen characterized this issue:

> I was the only one from our school, and everybody that went to it [was] from different schools. But taking it back to my department, being excited and saying "Here's what we need to do." They [the other teachers in the department] kind of got it but not fully. So, I'm the only one that's really doing a lot of the NGSS things. I think that they did look at the content part of it and say "Oh, yes. We're covering this content." But they don't get the crosscutting concepts and the science and engineering practices. They don't look at those things as part of our curriculum, and part of the things that we need to be teaching those students. So I think, and that's not just my coworkers, but I think that's kind of across many of the different teachers that I've run into. (Kristen, Interview Transcript, December 8, 2017)

Professional development provided by state departments of education was largely viewed as negative. One participant expressed that it was the professional development provided by his department of education that turned him off to the standards.

For example, this Next Generation Science Standards we had a guy from the New Jersey Department of Education. He did a presentation about two years ago and so that's I guess how I was introduced to this next set of standards. He did his presentation. He did a really terrible presentation and the audience got really hostile. They pretty much ended up tuning out and that's about as far as it went. (Jameson, Interview Transcript, December 8, 2017)

**Perceived practicality: A summary.** Perceived practicality was identified as a weak predictor of receptivity by the holistic regression model and was not identified as a predictor of
receptivity by any of the subject-specific models. The identified themes, concerns about state
testing, the lack of concrete examples of NGSS aligned instruction, and problems with the
quality and accessibility of professional development all operated largely outside of teachers’
control.

**Issues of concern.** Issues of concern were also only identified as a significant predictor
of receptivity by the holistic model. Issues of concern focused on one theme, deficits in science
instruction at the elementary and middle school level. The deficits in science instruction in the
lower grades caused students to be unprepared to engage in inquiry. This theme appeared in the
transcripts of both receptive and non-receptive teachers.

Unpreparedness to engage in inquiry was largely placed by these participants at the feet
of elementary school teachers. Jana, a resistant chemistry teacher, summarized this by saying
“elementary teachers don't really like science because they're afraid of it. And so the kids don't
get that experiential activities or whatever you want to call them that early” (Jana, Interview
Transcript, December 14, 2017). Timothy’s response provided more clarity:

The biggest concern that I have is that with trying to implement NGSS in the high school,
when these kids that we have, like I said, haven't had science prior to seventh grade, they
don't have a foundation. They don't, they haven't been brought up in that mode of
thinking...elementary school teachers, a lot of them have limited or no training in science
and they're just trying to get by with their reading and math classes and this is just
another layer of work for them...if a student hasn't been taught how to think critically and
how to think science in elementary school, when they get to me, I'm still going to have to
hold their hands and ride in on my white horse to save them. When they can't get over
that thought hurdle, it's too late. (Timothy, Interview Transcript, December 15, 2017)
Answering the Research Questions

This explanatory sequential study sought to answer five research questions using a survey and semi-structured interviews. This section provided a summary of the answers to these questions.

**What factors contribute most to high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?** This question was answered by quantitatively analyzing the survey responses from all high school science teachers. The factors that contributed most to high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS were teacher’s non-monetary cost-benefit analysis, perceived practicality, and issues of concern.

Cost-benefit analysis specifically focused on the satisfaction with teaching in relation to the by teaching to the, teachers’ views on the NGSS’s improvement in science literacy among students, and teachers’ view of student engagement in science under the NGSS. Perceived practicality focused on teachers’ view of the NGSS in relation to meeting the curricular needs of their students. Issues of concern focused on the impact of the NGSS in terms of the time available to teach subject-specific content.

**What factors contribute most to high school biology teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?** This question was answered by quantitatively analyzing the survey responses from teachers who were identified as solely biology teachers. Only one factor, non-monetary cost-benefit analysis, contributed to high school biology teachers’ receptivity to the curricular shifts necessitated by the adoption the NGSS.

**What factors contribute most to high school chemistry teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?** This question was answered by
quantitatively analyzing the survey responses from teachers who were identified solely as chemistry teachers. Only one factor, non-monetary cost-benefit analysis, contributed to high school chemistry teachers’ receptivity to the curricular shifts necessitated by the adoption the NGSS.

**What factors contribute most to high school physics teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?** This question was answered by quantitatively analyzing the survey responses from teachers who were identified solely as physics teachers. Only one factor, non-monetary cost-benefit analysis, contributed to high school physics teachers’ receptivity to the curricular shifts necessitated by the adoption the NGSS.

**Why are the identified factors involved in receptivity an issue for biology, chemistry, and physics teachers respectively? and How do the identified factors operate in the classrooms and experiences of biology, chemistry, and physics teachers?** In the holistic model, three factors were identified as statistically significant. In the subject specific models, only non-monetary cost-benefit analysis was identified as significant. For all of the teachers who participated in the qualitative portion of the study, the time required to adapt lessons to the NGSS were seen as the greatest cost. This was true of both receptive and non-receptive teachers. Differences in receptivity were seen in the teachers’ perspectives of the benefits of the NGSS and whether those benefits for their students outweighed the costs to the teachers.

The holistic model identified perceived practicality as a significant predictor when science teachers from all content backgrounds were included. For teachers, perceived practicality focused on three themes: problems with high-stakes testing, lack of concrete examples of NGSS aligned instruction, accessibility of high-quality professional development. State-level decisions about high-stakes testing were outside of teachers’ control. Depending on the state, student
outcomes from state testing could have an impact on teachers’ certification or advancement. For teachers in states that had adopted the NGSS but continued to test on the old standards, there was no impetus to change, as this could result in lower scores for their current students and the possibility of negative consequences for themselves.

The lack of concrete examples of NGSS-aligned instruction influenced teacher receptivity. Textbook publishers had not caught up with the NGSS and many of the materials published in recent years were not fully NGSS-aligned. This forced teachers to create materials from “scratch for an outcome they could not fully describe. Teachers in the qualitative sample also noted that concrete examples of NGSS-aligned instruction were not provided in professional development meetings.

Problems accessing high-quality professional development also influenced receptivity. The teachers in this study who were able to access high-quality professional development noted that doing so required them to take their own time, in the summer, to attend and that the experience was disassociated from their colleagues. Low-quality professional development appeared, from this group of participants, to abound but did not result in the understanding of the NGSS necessary to facilitate implementation and had the power to turn participants off from the NGSS.

The holistic model also identified issues of concern as a significant predictor when science teachers from all content backgrounds were included. The issue of concern noted by teachers in the follow-up interviews was inadequate science preparation at the elementary and middle school level.
Chapter 5: Findings and Discussion

Introduction

The purpose of this explanatory sequential, mixed-methods study was to identify and compare the factors that influenced science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS, in the traditional disciplines of biology, chemistry, and physics. This chapter begins with a summary of the problem of practice addressed by this research and a restatement of the research questions. The next section briefly introduces the findings of this study and discusses them in conjunction with the research literature. This is followed by a discussion of the relationship of the findings to the theoretical framework. After situating the findings of this study within both the research literature and the theoretical framework, its limitations are delineated. This chapter concludes with a discussion of the implications of these findings for scholarship, policy, and practice.

Problem of Practice and Research Questions

Science education has been a focus of American education policy (Ravitch, 2010; Ravitch; 2013; Basile & Lopez, 2015) since the publication of A Nation at Risk (United States National Commission on Excellence in Education, 1983). Success in science education, at the K-12 level, remains a priority to policymakers who are concerned with maintaining American economic prominence (NGSS Lead States, 2013; NRC, 2012). The NGSS, which were released in 2013, are the biggest change to American science education since 1996 when the NSES were published. Since their release, 19 states and the District of Columbia have officially adopted the standards and several other states have adapted them.

The NGSS are markedly different from current practice and pedagogy at all levels of the K-12 education spectrum. The NGSS focus on the areas of life science, physical science, and
Earth and space science (NRC, 2012) and specifically suggest that schools adopt an integrated model of science instruction (NRC, 2012; NGSS Lead States, 2013). This stands in stark contrast to the traditional biology, chemistry, and physics model that exists in most American high schools (Yager, 2015). It is important to note that this model of life science, physical science, and Earth and space science is common at the middle school level. Additionally, science instruction and assessment at the high school level has traditionally focused on the acquisition of factual knowledge rather than the process of developing scientific knowledge though inquiry (NRC, 2012; Pruitt, 2015; Marx & Harris, 2006).

Significant research has been done in the area of teacher reactions to curriculum change and change resistance (Craig, 2012; Mutch, 2012; Waugh & Godfrey, 1993; Waugh & Punch, 1995; Chi-Kin Lee, 2000). However, this research was not specifically focused on science education. The NGSS offers the opportunity to focus curriculum change research on science education, particularly at a time when the current model of science education at the high school level is undergoing a dramatic shift (Yager, 2015).

The central research question for this study was: What factors influence high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS? The sub-questions for this study were:

1. What factors contribute most to high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?

2. What factors contribute most to high school biology teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?

3. What factors contribute most to high school chemistry teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?
4. What factors contribute most to high school physics teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS?

5. Why are the identified factors involved in receptivity an issue for biology, chemistry, and physics teachers respectively?

6. How do the identified factors operate in the classrooms and experiences of biology, chemistry, and physics teachers?

**Presentation of Findings**

The central research question for this explanatory sequential mixed-methods study was: What factors influence high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS? The findings of this study are summarized in Figure 7 below and are discussed, in detail, along with their relationship to the established literature in the three subsequent sections.

*Figure 7. Synopsis of findings.*
Finding 1: Non-monetary Cost-Benefit Analysis

The quantitative data analysis for this study used multiple linear regression to identify the factors that contributed most to high school science teacher’s receptivity to the curricular shifts necessitated by the adoption of the NGSS. Five models were constructed from the survey data provided by participants. The first and second models included teachers from all high school science subject areas as well as those who taught multiple science subjects. Three subject specific models were constructed: the biology model, the chemistry model, and the physics model. All of these models identified teachers’ non-monetary cost-benefit analysis as a significant factor in receptivity. In fact, within the three subject-specific models, only teachers’ non-monetary cost-benefit analysis was significant. Follow-up of the quantitative findings was accomplished through interviews with a sample of receptive and non-receptive participant volunteers. In an explanatory sequential mixed-methods study, the role of the qualitative investigation is to explain and expand the quantitative findings.

Non-monetary cost-benefit analysis has also been found by other studies to be a significant factor in teacher’s receptivity to change. Both Waugh and Godfrey (1995) and Moroz and Waugh (2000) describe teachers’ non-monetary cost benefit analysis as a significant predictor of teachers’ receptivity to curriculum change in other contexts. Further, Doyle and Ponder (1977) defined teachers’ non-monetary cost-benefit analysis as a ratio of the amount of work for the teacher versus the rate of return for their students.

Time as cost. Time, for teachers, exists on two levels. There is planning time and curricular time. Planning time is the time it takes to design lessons. Planning time can occur within the course of the school day. It can also occur during a teachers’ personal time, such as
when the teacher is at home, over the weekend, and even when school vacations occur. Curricular time is the time it takes to teach lessons.

For all teachers who participated in the qualitative interviews, cost was defined as both planning time and curricular time. That is, the additional time it takes to adapt lessons to the NGSS and the time it takes to teach through inquiry, as suggested by the NGSS. Teachers repeatedly noted that this time cost was not offset by changes at the school level, meaning that the time required to make this transition with their lessons needed to come out of their personal time. This negativity impacted their satisfaction with teaching. This finding was consistent with established research on curriculum change (Waugh & Punch, 1983; Chi Kin Lee, 2000) and was true of receptive teachers and non-receptive teachers.

Teachers also noted that teaching in a way that used the practices of science and engineering as a vehicle for instruction required more instructional time than teaching using direct instruction methods. What could be covered in a single class period using direct instruction may take several more class periods when done through inquiry. Prior research has determined that inquiry science takes longer than direct instruction (Morrison, 2013; DiBiase & McDonald, 2015; Krajcik, Blumenfeld, Marx, Bass, & Fredericks, 1998). In addition, inquiry demands additional time for teachers’ daily lesson planning and preparation (Songer, Lee, & Kam, 2002) which can carry over into a teachers’ personal time.

**Weighing the benefits.** While the discussion of costs was universal, encompassing both receptive and non-receptive teachers of all disciplines, the discussion of the benefits was not. Doyle and Ponder (1977) defined the benefits side of the cost-benefit analysis as the rate of return on the costs incurred by teachers during a change. The benefits of the NGSS, as recognized both by the authors of the standards and the teachers in this study were college and
career readiness. It was important to note that two of the non-receptive teachers saw the NGSS as having no benefit in any of these areas.

Teachers who saw the NGSS as having any benefit identified the standards as preparative for many of the “soft skills” needed for success outside of school and defined this as college and career readiness. These skills included problem solving, dealing with uncertainty and failure, working collaboratively, and engaging in argument from evidence (Adams, 2012; Kasza & Slater, 2017; Mcdonald, 2017).

The quantitative analysis, particularly from the exploratory model, as well as findings from many of the interviews also pointed to the NGSS as improving students’ science literacy. The focus on developing scientifically literate citizens is clearly stated in both the NGSS document and the framework for K-12 Science Education (NRC, 2012; NGSS Lead States, 2013). A scientifically literate citizen should be able to “evaluate the quality of scientific information on the basis of its source and the methods used to generate it” and possess the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately” (NRC 1996, p. 22).

**Finding 2: Issues of Alignment**

In the holistic model perceived practicality was found to be a significant, though weak, predictor of receptivity. For the purposes of this discussion, the scale on the survey instrument named, “perceived practicality” had been renamed, “issues of alignment”, to better reflect the findings of this study. Teachers’ perception of the practicality of the NGSS were heavily influenced by their view of the alignment between the NGSS and their current teaching style. In follow-up interviews, teachers discussed this in three ways: problems with high-stakes testing,
lack of concrete examples of NGSS aligned instruction, and accessibility of high-quality professional development.

When discussing means to maximize student growth, teachers often talk about utilizing Vygotsky’s zone of proximal development (Vygotsky, 1980) as a means of helping students to grow by having them work with peers who are at a slightly higher level. Rogan (2006) transforms the idea of a zone of proximal development to a zone of proximal innovation. According to Rogan, the zone of proximal innovation is a “collection of teaching strategies that go beyond current practice, but are feasible given the existing resources available to that teacher, or group of teachers, and the prevailing environment of the school in terms of its ability to foster and sustain innovation” (Rogan, 2007, p.441).

All three findings under the heading of “issues of alignment” could be understood through the lens of the zone of proximal innovation.

**Misalignment between the NGSS and current high-stakes testing.** In the qualitative interviews, several teachers discussed the issue of high-stakes testing as affecting their view of the practicality of the NGSS. For most of the teachers in the qualitative part of this study, high-stakes testing in their state still followed the old standards. New testing was slated to begin within the next year for teachers in some states, while teachers in other states, particularly states like New Mexico that are recent adopters, would not see NGSS-aligned testing for several years. This issue of testing was important because if students were not being assessed on the NGSS, it was not in students’ or teachers’ best interest to teach to the NGSS. The presence of testing that was aligned to other standards pushes NGSS-aligned curriculum change outside the zone of proximal innovation (Rogan, 2007).
Tell me what this looks like in my classroom.

Teachers pointed to the lack of concrete examples of what NGSS-aligned instruction looked like in practice. In their focus on three-dimensional learning and their use of inquiry as the primary means of instruction, the NGSS go beyond current teaching practice. Most practicing teachers have not trained for this type of a system and require supports and scaffolding to teach in this way. Examples of instruction could serve as the scaffolding needed to bring teachers within the zone of proximal innovation (Rogan, 2007). For the NGSS, this meant that teachers need exemplars of grade-appropriate three-dimensional instruction that they could implement in their classrooms and use as a guide in formulating future instruction.

This finding highlights the research-practice gap that exists surrounding inquiry in science. Though inquiry science is not new, evidence from research suggests that it is poorly integrated into science instruction (Lebak, 2015; Capps & Crawford, 2013). Examples of NGSS-aligned instruction exist in a number of places including the NGSS Hub hosted by NSTA. Inquiry-based textbooks, like the Interaction Science Curriculum Project series, BCBS Biology, CHEM Study, and PSSC Physics are available. A recent study of the Interaction Science Curriculum Project series (Kraus & Shapiro, 2018a; Kraus & Shapiro, 2018b) found strong alignment between a textbook series from the late 1960s and the NGSS. BCBS Biology is the source of the 5E instructional model. It is also important to note that there is a wealth of non-inquiry based textbooks that are widely adopted.

The discourse surrounding the NGSS, with regard to its revolutionary nature, is also problematic and constitutes further evidence of the research-practice gap. Articles published in K-12 practitioner journals by prominent figures in the science education community have hailed the NGSS as a revolution in science education (Pruitt, 2015; Yager, 2015; Krajick 2015). Both
the NGSS document itself and the Framework for K-12 Science Education argue that they are an evolution of previous work (NRC, 2012; NGSS Lead States, 2013).

Claiming the NGSS are new is disingenuous and ignores the history of science education reform in the United States and the work that has been done in the area of reform-based science teaching. Inquiry science is not new! In fact, the history of inquiry in science education, in the form described by the NGSS, can be traced back to the middle of the 20th century (Schwab, 1962; Herron, 1971).

**Teach me how.** Participants also discussed the lack of high-quality and easily-accessible professional development as impacting their view of the practicality of the NGSS. All professional development is not created equal. Several participants had the opportunity to attend high-quality professional development programs like Modeling Instruction (Hagg & Megowan, 2015) and the NGSX training. These professional development programs involve long-term engagement, which has been shown to increase the efficacy of professional development (Gerard et al., 2011; Peneul et al, 2007). Other participants had low-quality NGSS professional development and cited the fact that poorly constructed or poorly delivered professional development had a negative impact on their view of the NGSS.

The research literature provided further evidence that effective professional development required continued engagement, rather than a one-off session (Moon, Passmore, Reiser, & Michaels, 2014). Further, it needs to focus on a specific content area, align to a set of internal or external goals, occur over a period of time, enable teachers to experience the content and methodologies that they will use, and provide direct instruction on how to use new materials (Wilson, 2013).
Professional development can also be understood in the context of the zone of proximal innovation (Rogan, 2007). It can serve as a bridge to help teachers move beyond current teaching strategies to new practices and teach them to use existing materials in new ways (Kilagon et al., 2008; Herrington et al., 2016). Further, by allowing teachers to connect with near-adVincentd peers, teachers can also make use of the zone of proximal development (Vygotsky, 1980) to improve their own skills.

**Finding 3: Concerns about Student Preparation**

The final factor identified by the holistic model is concerns about students’ preparation to be part of an NGSS classroom. This concern came in two forms: preparation to engage in NGSS-aligned instruction while in high school and preparation for college-level science coursework. Instruction in elementary school provides the foundation for future study in science (Duschl, Schweingruber, & Shouse, 2007). Yet, science instruction receives less instructional time than other subjects at the elementary school level (Blank, 2013). Further, elementary school teachers report feeling unqualified to teach science (Sandholtz & Ringstaff, 2014). Among the high school teachers interviewed for this study, deficiencies in their students’ science instruction at the elementary and middle school levels raised concerns about students’ ability to engage in science learning at the level specified by the NGSS in high school.

Preparation for college-level science coursework was also presented as a concern about student readiness. Preparation for college-level science coursework was separated by teachers into preparation for laboratory work and preparation for coursework. Greater agreement existed among participants about students’ readiness for college-level laboratory work than on their preparation for college science courses that focused on content. Even some receptive teachers expressed concerns about students’ preparation for college-level science coursework because
NGSS did not provide some of the prerequisite knowledge required for college-level study in certain disciplines. Physics and chemistry teachers spoke to deficiencies in mathematics within the NGSS. These concerns about college readiness are not without merit. Mcdonald (2015), in an article in the Journal of College Science Teaching, posits that students coming from an NGSS background will be prepared differently than previous students and that college-level science instructors need to take these differences in preparation into account.

**Theoretical Framework**

Windschitl’s Framework of Dilemmas (2002) was used as the theoretical framework for this study. Windschitl’s Framework defined dilemmas as aspects of “teachers’ intellectual and lived experiences that prevent theoretical ideals of constructivism from being realized in practice in school settings” (p. 132). Using the precedent set by other studies that have used this framework (Cushion, 2013), a dilemma for the purposes of this study was defined as an aspect of teachers’ intellectual or lived experience that prevented the theoretical ideals of the NGSS from being integrated into classroom practice.

Windschitl (2002) identified four categories of dilemmas: conceptual dilemmas, pedagogical dilemmas, cultural dilemmas, and political dilemmas. In essence, Windschitl’s framework describes how dilemmas operate at different levels and engage with multiple actors. This is shown below in Figure 8. Conceptual dilemmas are self-contained, arising from the teacher’s understanding of the subject matter or their beliefs regarding teaching and learning. Pedagogical dilemmas begin to reach out from the teacher and arise from the challenges in designing curriculum and instruction to help students meet the NGSS. Cultural dilemmas exist within the classroom dynamic and emerge between teachers and students as the orientation of the classroom is reconstructed to align with the NGSS. Political dilemmas exist at multiple levels,
within the school community as a whole, between the school and parents, and between the school and broader society.

*Figure 8. Continuum of dilemmas.*

The three findings of this study could be understood within Windschitl’s Framework though they do not break down neatly along his proposed continuum. That is, each finding could be placed at different points along the continuum. A synopsis of the findings of this study, situated within Windschitl’s Framework, can be found in Figure 9. The biggest takeaway from this study was the fact that factors involved in teacher receptivity to the NGSS operated at multiple levels of Windschitl’s Framework. Classifying dilemmas in this manner was useful as it provided guidance for developing interventions to help teachers’ overcome the dilemmas they faced implementing change in their classrooms.

*Figure 9. Situating the findings of this study within Windchistl’s Framework.*

**Finding 1: Non-monetary Cost-Benefit Analysis**
Teachers’ non-monetary cost-benefit analysis was found to be a significant predictor of receptivity to the NGSS. Further, this analysis could be broken down into costs for teachers, in terms of planning and instructional time, and benefits for students, in terms of career and college readiness.

Non-receptive teachers saw the costs of transitioning to the NGSS as outweighing the potential benefits. This factor operated at multiple levels within Windchistl’s Framework. Costs and benefits are conceptual dilemmas when they interact with teachers’ beliefs, which influence their classroom practice and are the lens by which teachers approach curriculum (Glackin, 2016; Laplante, 1997). Teacher beliefs play a role in how they viewed the purposes of science education, how they used planning time, and their pedagogical choices. For example, if a teacher held the belief that their role was to train future scientists, then the college and career benefits of the NGSS may not be immediately evident or deemed worthwhile.

Costs and benefits are also pedagogical dilemmas, as they challenge teachers to design instruction to help students meet the NGSS. Teaching via inquiry takes longer, in terms of curricular time, than teaching though more direct modalities, such as lecture (Morrison, 2013; DiBiase & McDonald, 2015; Krajcik, Blumenfeld, Marx, Bass, & Fredericks, 1998). When this increased need for class time is not met, teachers are faced with a pedagogical dilemma. In addition, teaching the “soft-skills” necessary for college and career readiness may be outside teachers’ pedagogical content knowledge (Lederman & Gess-Newsome, 1992), setting up another pedagogical dilemma.

Finding 2: Issues of Alignment
Alignment between a teachers’ instructional style and the NGSS was found to be a weak predictor of teacher receptivity, as it was overshadowed by cost-benefit considerations. Misalignment of teaching style and the NGSS impacted teachers’ perceptions of the practicality of the NGSS and like cost-benefit analysis, operates at multiple levels within Windchistl’s Framework.

The continued presence of high-stakes testing not aligned to the NGSS was one issue that represented both pedagogical and political dilemmas. As a pedagogical dilemma, teachers in states where testing aligned to standards other than the NGSS, are placed in a positon where teaching to the NGSS could hurt their students’ high-stakes test scores. Depending on the state, this could negatively impact their job performance, which could affect their certification or eligibility for a raise. This is also a political dilemma, as it engages teachers, school boards, and state departments of education in the politics of changing standards.

The lack of concrete examples of NGSS aligned instruction is both a conceptual and a pedagogical dilemma. Failure to understand what NGSS-aligned instruction looks like it is a conceptual dilemma. Understanding what this instruction looks like, but lacking the pedagogical knowledge and pedagogical content knowledge to design NGSS-aligned instruction is a pedagogical dilemma. Examples of NGSS-aligned instruction could help teachers overcome the conceptual dilemma of not understanding what NGSS-aligned instruction looked like and could help scaffold their teaching as they learn the pedagogical skills necessary to implement the NGSS in their classrooms.

Accessibility of high-quality professional development is a political dilemma as it reaches outside of the school and engages a broad range of actors. These include purveyors of professional development, professional organizations of science teachers, state departments of
education, school administrations, and teachers. High-quality professional development aligned to the NGSS exists but may be unavailable to teachers due to the cost of attendance, program length, accessibility in terms of location, and timing of offerings. All of these variables exist outside of teachers’ or schools’ control.

The presence of low-quality professional development that purports to be aligned to the NGSS, exacerbates this political dilemma. It siphons off resources that could be used to provide high-quality training that prepares teachers to teach to the NGSS while simultaneously reinforcing existing negative feelings about professional development.

**Finding 3: Concerns about Student Readiness**

The NGSS are a set of K-12 standards that build upon each other. As such, foundational skills and knowledge that are taught in the lower grades are necessary for success in higher grades. In fact, in appendices to the NGSS clearly delineate the learning progressions for the DCI, CCC, and PSE (NGSS Lead States, 2013). Teachers’ concerns about students’ readiness to engage in scientific inquiry at the level required in high school by the NGSS are situated in current deficits in science instruction in the lower grades. This presents pedagogical, cultural and political dilemmas for teachers.

In terms of pedagogical dilemmas, high school teachers are faced with students who lack adequate preparation to participate in NGSS-aligned instruction at the high school level. Designing instruction aligned to the NGSS for students with inadequate preparation challenges teachers’ pedagogical content knowledge (Park & Chen, 2012). Additionally, the NGSS expect teachers to largely shift classroom pedagogy to an inquiry and project based approach to learning. For some teachers unfamiliar with these methods, this presents additional pedagogical dilemmas as they endeavor to design instruction for their students.
Deficits in science instruction in the lower grades also create cultural dilemmas. For students entering a high school science classroom aligned to the NGSS, science instruction may be markedly different than it was in the lower grades. The NGSS require students to act as scientists through their engagement with the PSE. In an NGSS classroom, students are expected to develop questions, formulate hypotheses, design experiments, analyze data, and justify conclusions. Students who expect to be lectured to and then assessed solely through tests, may push back against this new formulation of classroom culture because this type of instruction falls outside their internal constructs of what a science classroom looks like.

Finally, deficits in science instruction in the lower grades are a political dilemma. The demands set forth by NCLB to demonstrate AYP in ELA and mathematics have forced a narrowing of the curriculum at the elementary level (NCLB, 2002; Ravitch, 2010; Ravitch, 2013; Vogler, 2011). Further, requirements for elementary level science teacher preparation are less robust than at higher grades (Hanuscin & Zangori, 2016; Olsen, Tippett, Milford, Ohana, & Clough, 2015). A broad range of research shows that elementary school teachers have low levels of science pedagogical content knowledge and negative attitudes towards teaching science (Harlen & Holroyd, 1997; Palmer, 2004; Van Aalderen-Smeets, Walma van der Molen, & Asma, 2012).

The disconnect between the NGSS and teachers’ view of college-level science preparation is also a political dilemma, as it reaches beyond the interactions that occur within the classroom between students and teachers. High school science teachers hold certain views about what is necessary for success in college-level science coursework based on their own experience as students and teachers. Mcdonald (2015) acknowledges that students prepared under the NGSS will have different foundational knowledge and skills than students prepared under the previous
standards. For teachers of AP-level science courses who participated in the qualitative interviews, the discussion of the deficits brought on by NGSS-aligned instruction centered on specific prerequisite content and skills for success in AP-level courses. Similar assertions were made by non-AP teachers about students’ preparation for college-level science coursework.

**Limitations**

All types of research are bound by certain limitations. This explanatory sequential, mixed-methods study used a survey and interviews to identify and describe the factors that contributed to high school science teachers’ receptivity to the NGSS. For this study, there were several limitations that stemmed from the survey used to gather data. National and state listservs of science teachers were used to disseminate this survey. In order to receive the invitation to complete the survey, teachers needed to be a member of one of the organizations that agreed to distribute the survey and they needed to subscribe to the organization’s listserv. While it would appear that these are one and the same, several of the organizations separate subscription to the listserv from organization membership. Additionally, membership in professional organizations of science teachers option and thus not universal. Teachers who become part of these organizations may not be representative of all science teachers. In addition to the limitations inherent to survey research, this study was also limited in its generalizability, due to the small sample size and lack of response rate.

Upon receiving the survey, participants needed to choose to complete the survey. This use of volunteers potentially biases the data (Dillman, Smyth, & Christian, 2014; Sapsford, 2017). The issue of volunteerism also affected the qualitative portion of the study, as participants needed to volunteer, within the survey, to participate in follow-up interviews. More receptive teachers provided contact information than non-receptive teachers. Also, given that these
interviews are qualitative in nature, their responses are specific to the participants and may not represent the views of the entire sample.

Different programs at the state level also added to the limitations for this study. Currently, states fall into three categories as it relates to the NGSS: adopting states, adapting states, and non-NGSS states. This study looked only at responses from high school teachers in states that had adopted the NGSS. States have adopted the NGSS at different times. All NGSS states are at different points in implementation, making it difficult to draw comparisons between states.

This was further complicated by differences in science educator certification between states. Significant differences in areas of certification and requirements for certification exist between states. For example, Rhode Island does not offer a certification in Earth science while other states, like Michigan and New Hampshire do. Additionally, some states required coursework to obtain a teaching certification, while other states accepted subject Praxis test scores as evidence of content knowledge.

**Implications**

Even with the stated limits in the above section, the findings of this study have implications for scholarship, policy, and practice. This section discusses these implications and situates them within current research.

**Implications for Scholarship**

The work done in this study provided a foundation for future work on science teachers’ receptivity to the NGSS. First, teacher receptivity to the NGSS needed to be examined at the elementary, middle, and college level. Factors involved in science teachers’ receptivity to the NGSS in this study connected to receptivity at other levels. For example, teachers cited deficits
in science education at the lower grades. Current research supports the idea that elementary science teachers are inadequately prepared to teach science and have negative attitudes towards science (Harlen & Holroyd, 1997; Palmer, 2004; Van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). Further research needs to be done to see if this continues to hold true under the NGSS.

High school science teachers expressed concerns about students’ preparation for college-level science coursework. Mcdonald (2015) acknowledges that students who are taught under the NGSS will be prepared differently than students of previous generations. Research on college science teachers’ receptivity to the NGSS could serve to alleviate high school teachers’ fears or begin a dialogue between the levels.

This study focused solely on high school science teachers in states that have adopted the NGSS. As of this writing, 17 additional states have adapted the NGSS to their state’s preexisting science standards. While these participants were excluded from this study, important information could be gleaned from examining teacher receptivity in these states.

In general, there is more work to be done on science teachers’ receptivity to the NGSS. Given the significant disparities in state-level education policy, particularly in terms of testing and certification, a larger study with a more representative sample of science teachers for each state is needed to assess receptivity to the NGSS among science teachers.

In addition to studying teachers’ receptivity to the NGSS, it is important to examine the institutional and structural barriers that are in place and prevent the NGSS from being implemented with fidelity. Schools like High Tech High and the Big Picture Schools offer a chance to examine implementation of the NGSS in an environment that works outside of the
constraints, such as traditional academic departments and defined class periods, which exist in the majority of American public schools.

**Implications for Policy**

The findings of this study also have significant implications for policy at the state and local level. One of the key findings was that high school teachers perceived deficits in science instruction at the lower grades. This could be addressed through changes in elementary and middle-level teacher preparation and certification. Current research suggests that elementary-level teachers receive inadequate preparation for teaching science in programs of teacher preparation (Harlen & Holroyd, 1997; Thomas & Pederson, 2003; Palmer, 2004; Smith & Jang, 2011).

Another way that this could be addressed is by strengthening science education requirements in grades K-8. Currently, vast differences exist between schools in the amount and quality of science instruction (Douville, Puglee, & Wallace, 2003; Duschl et al., 2007; Blank, 2013). In order to be successful under the NGSS, students need consistent exposure to high-quality, NGSS-aligned science instruction beginning in kindergarten and continuing all through their schooling. State departments of education can facilitate this by increasing the amount of time schools must devote to science instruction and relaxing other constraints to make this time allocation possible. Individual school districts do not need to wait for state-level policy makers to act, they can make changes now.

The final policy implication for this study was that misalignment between high-stakes testing and the NGSS was detrimental to implementation. Some states, like Rhode Island and Michigan, have adopted the standards, but left their non-NGSS aligned state test in place until an NGSS-aligned test was ready for piloting due to NCLB mandates. This misalignment
discourages innovation and transition to the NGSS, as the prior state standards do not align with the NGSS. Research on organizational change outside of education has found that removing obstacles from the paths of early adopters can lead to better outcomes (Lewin, 1947; Elrod & Tippett, 2002). The continued presence of non-NGSS aligned assessment remains a significant obstacle for teachers that are ready to begin transitioning.

Implications for Practice

At the school level, administrators need to take teachers non-monetary, cost-benefit analysis of the NGSS seriously. Transitioning the NGSS is a labor intensive activity, often requiring teachers to rewrite or redesign lessons to align them with the inquiry focus of the standards (Songer, Lee, & Kam, 2002). This work requires more time than teachers have in the course of normal planning and adjustment for that time cost needs to be taken into account as teachers begin to transition their curriculum. This support can take the form of additional planning time, streamlining teachers’ schedules to allow them to focus on a single subject area, and/or encouraging the development of communities of practice within schools.

Science teacher educators and professional organizations of science teachers need to help teachers learn to teach to the NGSS by making exemplars available for teachers to use in their classrooms. Teaching to the NGSS, in many ways, is a significant transition from previous models of science instruction and teachers need support to make these changes reality. Exemplar lessons can serve as scaffolding for teachers by bringing down the level of abstraction of NGSS-aligned instruction and bringing this change within the zone of proximal innovation (Rogan, 2007).

Finally, teachers need to be able to access high quality, professional development. While this may sound like a simple implication, it may be the most difficult to implement. High-quality
professional development is sustained over time, allows teachers engage with the standards, and provide tools for teachers to bring back to their classrooms. Many of the professional development programs that meet these criteria occur during the summer, require teachers to travel, and come at a significant cost. Schools and state departments of education need to make high-quality professional development a priority and provide the resources, time and funding for teachers to attend.

**Conclusions**

The purpose of this explanatory sequential mixed-methods study was to identify and compare the factors that influenced high school science teachers’ receptivity to the curricular shifts necessitated by the adoption of the NGSS in the traditional disciplines of biology, chemistry, and physics. This study identified three factors as exerting significant influence over high school science teachers’ receptivity to the NGSS: teachers’ non-monetary cost-benefit analysis, alignment between their teaching style and the NGSS, and concerns about student readiness.

While subject area was posited to be a significant factor in teacher receptivity, a proposition that was supported by the literature review, it turned out not to be a significant factor in high school science teachers’ receptivity to the NGSS. Responses from participants in all subject domains expressed similar concerns about the factors that influenced their receptivity. This is important as it means that the different subject areas, at the high school level, do not require different treatment modalities to increase receptivity.

The NGSS mark a radical departure from prior practice in science education in terms of both content and pedagogy (Bybee, 2014; Pruitt 2014; Yager, 2015). This study indicated that among members of professional organizations of science educators, there are teachers who are
receptive to this change. Further, this study provides suggestions for steps that can be taken to increase the receptivity of teachers who are not currently onboard with the NGSS. Given their design and focus, the NGSS have the potential to improve science education in America and help in the development of a scientifically literate populace. However, this will only occur if those involved in the implementation of the NGSS take the steps needed to support teachers in their transition.
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Appendix A
Comparison of Survey Item Wording

Original Wording (Chi-Kin Lee, 2000)
Perceived non-monetary cost-benefit of the Guidelines to the teacher

(1) In weighing up the balance between the work generated for me by the Guidelines and my satisfaction with teaching, I think the Guidelines are worthwhile.

(2) In weighing up the balance between the work generated for me by the Guidelines and my improvement in environmental knowledge, I think the Guidelines are worthwhile.

(3) In weighing up the balance between the work generated for me by the Guidelines and improvement in classroom learning, I think the Guidelines are worthwhile.

(4) In weighing up the balance between the work generated for me by the Guidelines and the increased commitment towards improving environmental quality by the students, I think the Guidelines are worthwhile.

(5) In weighing up the balance between the work generated for me by the Guidelines and praise by my school principal, I think the Guidelines are worthwhile.

(6) In weighing up the balance between the work generated for me by the Guidelines and better environmental quality in schools and local communities, I think the Guidelines are worthwhile.

(7) In weighing up the balance between the work generated for me by the Guidelines and improvement in my professional status as a teacher, I think the Guidelines are worthwhile.

Revised Wording
Perceived non-monetary cost-benefit of the NGSS to the teacher

(1) I think the NGSS are worthwhile when weighing the balance between the work they generate for me and my satisfaction with teaching.

(2) I think the NGSS are worthwhile when weighing the balance between the work they generate for me and the changes in my teaching style it necessitates.

(3) I think the NGSS are worthwhile when weighing the balance between the work they generate for me and improvement in student learning.

(4) I think the NGSS are worthwhile when weighing the balance between the work they generate for me and the increased commitment towards improving science literacy by the students.

(5) I think the NGSS are worthwhile when weighing the balance between the work they generate for me and praise by my school principal.

(6) I think the NGSS are worthwhile when weighing the balance between the work they generate for me and better student engagement with science concepts and skills.

(7) I think the NGSS are worthwhile when weighing the balance between the work they generate for me and improvement in my professional status as a teacher.
Perceived practicality of the Guidelines
(1) The principle of experiential learning integral to EE suggested by the Guidelines suits my classroom teaching style.
(2) The EE principle of a balanced viewpoint maintained for environmental issues reflects my educational philosophy.
(3) The principle of encouraging the individual pupil’s contribution and participation suggested by the Guidelines is likely to be realized in my classroom context.
(4) The principles of implementing EE through both the formal and informal curriculum are appropriate to meeting the needs of the pupils in my school.
(5) The principle of forming positive environmental attitudes included in the Guidelines matches my knowledge and skills in teaching EE.

Issues of concern associated with implementing EE
(1) I am concerned that pupils have incorrect attitudes towards environmental issues.
(2) I am concerned that General Studies, Social Studies, Health Education and Science receive more attention than other subjects.
(3) I am concerned that the introduction of EE will result in lower academic performance among the students at this school.
(4) I am concerned that the introduction of EE will lead to less time being available for the teaching of the subject syllabus.
(5) The pupils’ abilities are causing me concern in regard to the teaching of EE at this school.
(6) Disciplinary problems are causing me concern in regard to the teaching of EE at this school.

Perceived practicality of the NGSS
(1) The principles of three dimensional learning that are integral to the NGSS and suggested by the Framework for K-12 Science Education suit my classroom teaching style.
(2) The NGSS practice of engaging in argument from evidence reflects my educational philosophy.
(3) The principle of encouraging the individual student’s contribution and participation suggested by the NGSS is likely to be realized in my classroom context.
(4) The principles of implementing the NGSS through both the formal and informal curriculum are appropriate to meeting the needs of the students in my school.
(5) The principle of supporting ideas with empirical evidence included in the NGSS matches my knowledge and skills in teaching science.

Issues of concern associated with implementing the NGSS
(1) I am concerned that students have incorrect attitudes towards science and engineering.
(2) I am concerned that English language arts and mathematics receive more attention than other subjects.
(3) I am concerned that the introduction of the NGSS will result in lower academic performance among the students at my school.
(4) I am concerned that the introduction of NGSS will lead to less time being available for the teaching of the content in my subject.
(5) The students’ abilities are causing me concern in regard to the teaching of NGSS at my school.
(6) Disciplinary problems are causing me concern in regard to the teaching of NGSS at my school.
Perceived school support for teaching EE

(1) There are regular meetings at which I can raise my worries and doubts about the implementation of EE.
(2) Whenever there are problems implementing EE, there is a senior teacher whom I can ask for advice.
(3) There is good support whenever I have problems, such as a shortage of books and equipment, related to EE.
(4) There are regular school-based talks or training programmes at which I can learn how to teach EE.
(5) The majority of teachers in this school support EE.
(6) The principal encourages teachers to participate in training courses related to EE.
(7) At school meetings, the principal makes comments emphasizing the importance of introducing EE at this school.

Perceived school support for teaching NGSS

(1) There are regular meetings at which I can raise my worries and doubts about the implementation of NGSS.
(2) Whenever there are problems implementing NGSS, there is a senior teacher whom I can ask for advice.
(3) There is good support whenever I have problems, such as a shortage of books and equipment, related to NGSS.
(4) There are regular school-based professional development programs at which I can learn how to teach to the NGSS.
(5) The majority of teachers in my school support the NGSS.
(6) The principal encourages teachers to participate in training courses related to the NGSS.
(7) At school meetings, the principal makes comments emphasizing the importance of introducing NGSS at my school.

Perceived other support for teaching EE in schools

(1) In my opinion, the government departments support the implementation of EE in my school.
(2) In my opinion, the Curriculum Development Institute and the Education Department provide sufficient suggestions and assistance to help teachers acquire the methods of implementing EE in my school.
(3) In my opinion, the environmental organizations in Hong Kong provide adequate support for promoting EE in my school.
(4) In my opinion, the majority of parents in this school supports the implementation of EE in this school.
(5) In my opinion, the local community organizations provide adequate environmental activities for pupil participation.

Perceived other support for teaching NGSS in schools

(1) In my opinion, the United States Department of Education supports the implementation of NGSS in my school.
(2) In my opinion, the state department of education provides sufficient suggestions and assistance to help teachers acquire the methods of implementing NGSS in my school.
(3) In my opinion, the science teacher organizations provide adequate support for promoting NGSS in my school.
(4) In my opinion, the majority of parents in this school support the implementation of NGSS in my school.
(5) In my opinion, the local community organizations provide adequate community resources for student participation.
Appendix B
Survey Instrument

Demographic Survey
The first section of this survey is designed to gather some demographic information about survey participants. Please complete the following questions.

In what state are you a high school science teacher?
[State list dropdown menu]

How many years have you been teaching?
[Dropdown menu with a range of 0-30+]

What is your gender?
[Male, Female]

What core high school science subject(s) do you teach? Check all that apply.
[Biology, Chemistry, Physics, Other, None]

What other high school science subjects do you teach?
[Open response]

What is your highest level of education?
[High School, Bachelors, Masters, Doctorate]

If masters is selected: Which of the following best describes your masters degree?
[Masters in education, Masters degree in a scientific discipline, Other]

If doctorate is selected: Which of the following best describes your doctorate?
[Doctorate in education, Doctorate in a scientific discipline, Other]

Which of the following best describes your undergraduate major?
[Scientific discipline, Scientific discipline and education, Other]

If not Other: What scientific disciplines did you major in?
[Biology, Chemistry, Physics, Earth Science or Geology, Astronomy, Engineering, Other]

If Other: What was your undergraduate major?
[Open response]

What teaching certifications do you hold? Check all that apply.
[Biology, Chemistry, Physics, General Science, Earth and Space Science, Other, Multiple]

What other teaching certifications do you hold?
[Open response]

What professional organizations do you belong to? Check all that apply.
[NSTA, NABT, AACT, AAPT, State Science Teacher Organization, None, Other]

Which of the following best describes the location of your school?
[rural, urban, suburban]

Which of the following best describes your school?
[Public, Charter, Private Religious, Private Independent, Other]

Approximately how many hours of professional development on the NGSS have you completed?
[0, 1-5, 6-10, 11-15, 16-20, 21+]

Select the descriptor below that best describes your level of knowledge of the NGSS.
[Highly Knowledgeable, Moderately Knowledgeable, Slightly Knowledgeable, Not Knowledgeable]

Select the description below that best describes your feelings about the workload of teaching to the NGSS.

[Significantly more work, Slightly more work, Equal work, Slightly less work, Significantly less work]

Main Survey

Mark the location on the scale that best represents how you feel toward the NGSS. The middle position (fourth space) represents a neutral position.

The adjective pairs are:

1. satisfied/dissatisfied [ ___ ___ ___ ___ ___ ___ ___ ___ ]
2. valuable/not valuable [ ___ ___ ___ ___ ___ ___ ___ ___ ]
3. wise/foolish [ ___ ___ ___ ___ ___ ___ ___ ___ ]
4. permissive/restrictive [ ___ ___ ___ ___ ___ ___ ___ ___ ]
5. intelligent/absurd [ ___ ___ ___ ___ ___ ___ ___ ___ ]
6. practical/impractical [ ___ ___ ___ ___ ___ ___ ___ ___ ]
7. effective/ineffective [ ___ ___ ___ ___ ___ ___ ___ ___ ]
8. necessary/unnecessary [ ___ ___ ___ ___ ___ ___ ___ ___ ]
9. uncomplicated/complicated [ ___ ___ ___ ___ ___ ___ ___ ___ ]

Indicate your level of agreement with each of the following statements

Perceived non-monetary cost-benefit of the NGSS to the teacher

1. I think the NGSS are worthwhile when weighing the balance between the work they generate for me and my satisfaction with teaching.
2. I think the NGSS are worthwhile when weighing the balance between the work they generate for me and the changes in my teaching style it necessitates.
3. I think the NGSS are worthwhile when weighing the balance between the work they generate for me and improvement in student learning.
4. I think the NGSS are worthwhile when weighing the balance between the work they generate for me and the increased commitment towards improving science literacy by the students.
5. I think the NGSS are worthwhile when weighing the balance between the work they generate for me and praise by my school principal.
6. I think the NGSS are worthwhile when weighing the balance between the work they generate for me and better student engagement with science concepts and skills.
7. I think the NGSS are worthwhile when weighing the balance between the work they generate for me and improvement in my professional status as a teacher.

Perceived practicality of the NGSS

1. The principles of three dimensional learning that are integral to the NGSS and suggested by the Framework for K-12 Science Education suit my classroom teaching style.
2. The NGSS practice of engaging in argument from evidence reflects my educational philosophy.
3. The principle of encouraging the individual student’s contribution and participation suggested by the NGSS is likely to be realized in my classroom context.
4. The principles of implementing the NGSS through both the formal and informal curriculum are appropriate to meeting the needs of the students in my school.
5. The principle of supporting ideas with empirical evidence included in the NGSS matches my knowledge and skills in teaching science.

Issues of concern associated with implementing the NGSS
1. I am concerned that students have incorrect attitudes towards science and engineering.
2. I am concerned that English language arts and mathematics receive more attention than other subjects.
3. I am concerned that the introduction of the NGSS will result in lower academic performance among the students at my school.
4. I am concerned that the introduction of NGSS will lead to less time being available for the teaching of the content in my subject.
5. The students’ abilities are causing me concern in regard to the teaching of NGSS at my school.
6. Disciplinary problems are causing me concern in regard to the teaching of NGSS at my school.

Perceived school support for teaching NGSS
1. There are regular meetings at which I can raise my worries and doubts about the implementation of NGSS.
2. Whenever there are problems implementing NGSS, there is a senior teacher whom I can ask for advice.
3. There is good support whenever I have problems, such as a shortage of books and equipment, related to NGSS.
4. There are regular school-based professional development programs at which I can learn how to teach to the NGSS.
5. The majority of teachers in my school support the NGSS.
6. The principal encourages teachers to participate in training courses related to the NGSS.
7. At school meetings, the principal makes comments emphasizing the importance of introducing NGSS at my school.

Perceived other support for teaching NGSS in schools
1. In my opinion, the United States Department of Education supports the implementation of NGSS in my school.
2. In my opinion, the state department of education provides sufficient suggestions and assistance to help teachers acquire the methods of implementing NGSS in my school.
3. In my opinion, the science teacher organizations provide adequate support for promoting NGSS in my school.
4. In my opinion, the majority of parents in this school support the implementation of NGSS in my school.
5. In my opinion, the local community organizations provide adequate community resources for student participation.

Follow-up Study Recruitment
Would you be interesting in participating in a follow-up interview on your perspectives of the challenges and benefits of implementing the NGSS?
[Yes, No]

If Yes: Enter your email address. Note by providing your email address your responses to the survey items become identifiable by the researchers. Your individual data will not be shared in any other way and you will not be identified individually in any publication based on this research.

[open response]
Appendix C
Qualitative Interview Protocol

Part A: Introductory Questions
*I am going to begin with some introductory questions to get to know you and your experience teaching science a little better.*

1. What grades and subjects do you teach?
2. Can you tell me about how you were introduced to the NGSS?
   Follow-Up Questions (if needed)
   Can you describe the professional development you have attended that focused on the NGSS?

Part B: Research Focused Questions
*I am interested in learning about how you feel about the transition to the NGSS. To do this, I am going to ask you some questions about your experiences with the NGSS and your understanding of the NGSS. Note that if you mention other people, please use do not mention names. Instead, give each person a pseudonym and note that you are using a pseudonym.*

   Let’s first discuss your cost versus benefit analysis of the NGSS.
3. What are some of the non-monetary costs you see associated with the NGSS?
   Follow-Up Question (if needed)
   How does teaching to the NGSS change how you use your planning time?
   What percentage of lessons have you had to eliminate or significantly revise?
   Has the NGSS changed the way you approach classroom instruction?
   How long does it take you to revise a lesson to align to the NGSS?

4. What are some benefits you see in the transition to the NGSS?
   Follow-Up Question (if needed)
   Can you describe these?

Now, I would like to discuss your perceptions of the practicality of the NGSS.
5. Do you see the change to the NGSS as practical? Why or why not?
6. What issues do you see as impacting the practicality of implementing the NGSS? Can you describe them?
7. How have your students reacted to the transition to the NGSS? Can you describe some examples?
8. Do you feel like the NGSS will help your students to be more college and career ready? Can you explain why or why not?
9. Do the NGSS align with the course structure and vertical articulation in your school? How does this impact your view of the practicality of the NGSS?

Next, I would like to discuss some of your issues of concern in implementing the NGSS.
10. Can you list any issues that concern you as it relates to the implementation of the NGSS?
    Follow-Up Questions (per issue listed)
    Can you describe this issue and give an example?

  Can you tell me about what supports are available in your school to help you in teaching to the NGSS?

11. Can you describe the attitudes of your fellow department members toward the NGSS?
    Follow-Up Question
How many science teachers are there in your department? How many are affected by the NGSS?

12. Can you describe the attitude of your principal or other building administrators toward the NGSS?

13. What other support have you received to implement the NGSS?

14. Has your school or school district made funding available for the purchase of new materials?

Follow-Up Question
Has this funding been adequate to acquire the new materials?

Finally, I would like to talk about how you and feel about the transition to the NGSS.

15. Are you supportive of the transition to the NGSS? Why or why not?