Teacher and Parent Perspectives on Alignment to the Next Generation Science Standards Following Teacher Professional Development

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TEACHER AND PARENT PERSPECTIVES ON ALIGNMENT TO THE NEXT GENERATION SCIENCE STANDARDS FOLLOWING TEACHER PROFESSIONAL DEVELOPMENT

by

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A dissertation submitted to the Graduate College in partial fulfillment of the requirement for the degree of Doctor of Philosophy
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Adam C. Channell
Science teachers are receiving professional development (PD) since the introduction of the Next Generation Science Standards (NGSS) in 2013. Following PD, teachers are facing several challenges while attempting to implement NGSS in their classroom, some of which include budget constraints, administrative support, and student preparedness (Banilower et al., 2013). Additionally, Channell and Cobern's (2018) study on teachers’ experiences aligning to NGSS following PD adds parent pushback to this list of challenges. This study seeks to address a set of interconnected issues related to teachers creating and administering lessons aligned to the NGSS that they have created following PD, and subsequent parent-teacher interactions that have resulted from use of these lessons with students.

This study is comprised of three manuscripts that outline three individual but related projects. A three-study model was used in this study because there are two separate parties involved, teachers and parents, and the lessons themselves require research attention. A group of 14 K-12 teachers participated in two of the studies simultaneously, with the first study revolving around teacher accounts of interactions with parents and the second focusing on evaluations of lessons teachers built following PD. Fifteen parents of K-12 students participated in a third study that gathered their feedback on NGSS awareness, approval or concern about their children’s
science education, and parents’ needs to help their students learn science at home. The three manuscripts are ordered within this study based on the relatability of the resulting data.

The first manuscript details a qualitative study comprised of survey and interview data from 14 K-12 teachers. By speaking directly to teachers about a specific, undocumented barrier during NGSS reform, this study expands on what the broad set of obstacles previously identified within the literature. The second manuscript describes a qualitative study made up of survey and interview data from 15 parents of K-12 students. By talking to these oft-ignored stakeholders in education, this study shows the current level of understanding parents have of NGSS, as well as reveal areas of both satisfaction and concern about their children’s science instruction. The third manuscript presents evaluations of lessons developed by 14 K-12 teachers following NGSS PD that were designed to align to the new standards. By contrasting evaluations on the teacher-built lessons performed by the participating teachers, and the researchers, with evaluative help from the PD practitioner who administered PD to the teachers, this study shows themes in strengths and weaknesses in lessons currently being used by teachers within the classroom. The results of this study may indicate as to the extent to which teachers’ current attempts at building NGSS lessons have been successful. This knowledge serves a dual purpose: to make an inference as to whether lesson quality has affected student learning, and in turn, parent feedback; and to serve to inform PD practitioners how to better tailor future PD sessions to address areas of weakness in lesson building. The cumulative results of the three studies build upon one another to help uncover ways to better inform parents about NGSS, improve communication between teachers and parents while attempting to align their classrooms to NGSS, and identify elements of teachers’ newly created NGSS lessons that need continued support in the form of PD.
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CHAPTER 1
INTRODUCTION

The Next Generation Science Standards (NGSS) were released in 2013, and since then, teachers are receiving professional development (PD) to aid in aligning their lessons and classroom practices to the new standards. However, the transition for teachers to become NGSS-aligned has presented challenges due to the three-dimensional organization of the standards. The disciplinary core ideas (DCIs) represent a reduction in the amount of raw content science teachers must cover, but the science and engineering practices (SEPs) and cross-cutting concepts (CCCs) that NGSS incorporates require teachers to teach in a dramatically different fashion (Duncan and Cavera, 2015). Some existing lessons that teachers have used in the past may need dramatic revisions, and in regard to some lessons, teachers will need a completely new approach (Kennedy, 2016). During this transitional process, teachers may struggle to build and execute new lessons (Shernoff, Sinha, Bressler, and Schultz, 2017). A lack of coherence in teaching can potentially have a negative effect on student understanding. Even when teachers have modified lessons and built self-efficacy to the point where they are well-aligned with NGSS, students may struggle to adjust to the new NGSS style of teaching and classroom set-up, especially since many students will not have gone through earlier grade levels encountering NGSS-style lessons (National Academy of Sciences, 2015). Either of these two scenarios invite the possibility for parents to become an obstacle for teachers as they attempt to align to NGSS, as parents have been recently shown to make complaints when their children are not scoring high marks or learning in their science classes (Channell and Cobern, 2018).
To better understand the relationship between teachers and parents in regard to NGSS and explore the connections between the quality of lessons teachers are using following PD, three separate manuscripts have been prepared to describe the overall results of this study. These manuscripts are framed by a review of the literature and operate under Fore, Feldhaus, Sorge, Agarwal, and Varahramyan (2015)’s Model of Subjectivity as a theoretical framework. The three manuscripts include:

1. Teachers’ Perspective on the Extent to which Parents Influence NGSS Implementation
2. Parent Accounts of Understanding and Support for NGSS
3. An Analysis of Teacher-Created NGSS-Aligned Materials

The three manuscripts describe a set of separate but interconnected studies. The first study investigates teacher experiences with parents while aligning to NGSS by conducting surveys and interviews with teachers. The second study investigates parent understanding of NGSS by conducting surveys and interviews with parents. The comments regarding parent interactions with teachers gathered in the first study could be related to the level of understanding parents have about NGSS. Additionally, the results of the first and second studies could collectively help district administrators, teachers, and PD practitioners realize how to better inform parents about NGSS. Finally, the third study looks into the quality of new lessons teachers are building to align to NGSS by having teachers evaluate their own lessons using the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric for science. The level of alignment quality to NGSS gathered in the second study could have connections to what kinds of complaints teachers are receiving about their lessons from the first study. An increase in parent awareness and support of NGSS could change parents from being obstacles for teachers into support figures, as
parents could reinforce to their children to trust the process of transitioning to NGSS-style learning. Having teachers and parents share a mutual understanding of the current situation with NGSS alignment would allow teachers more freedom to experiment with NGSS methods without fear of parent interference, as well as receive continued PD that addresses weaknesses in their lessons identified by the third study.

### 1.1 Theoretical Framework

The theoretical framework used throughout the overall study is conceptual change of teacher beliefs and practices through subjectivation, a process by which teachers evaluate the professional development (PD) experiences they encounter. The literature has a history of recognizing that teacher beliefs play a role in teacher change following PD. Guskey's (1986) Model of the Process of Teacher Change includes teacher beliefs as an outcome of staff development.

![Figure 1 Guskey's (1986) Model of the Process of Teacher Change](image)

Fore, Feldhaus, Sorge, Agarwal, and Varahramyan (2015) point out that Guskey's (1986) model assumes that a teacher’s practices and beliefs change directly from PD experiences, and does not factor in the prior knowledge and beliefs that teachers bring into PD experiences. Thus, Guskey's (1986) model removes the teacher as a subject from the process of teacher change.
However, it has been noted that teachers make connections with their prior knowledge when acting as learners, (Posner, Strike, Hewson, and Gertzog, 1982), and that beliefs and attitudes are critical components when teachers consider changing their practices (Briscoe, 1991; Haney, Czerniak, and Lumpe, 1996). Clarke and Hollingsworth's (2002) Interconnected Model of Professional Growth sought to build upon Guskey's (1986) model, incorporating teacher knowledge, beliefs, and attitudes as a personal domain that can play a role in reflection or enactment with the external domain (PD as a source of information or stimulus) and the domains of practice (the classroom) and consequence (student performance).

*Figure 2* Clarke and Hollingsworth's (2002) Interconnected Model of Professional Growth

As Fore, Feldhaus, Sorge, Agarwal, and Varahramyan (2015) note, the teacher as a subject is still potentially cancelled out in Clarke and Hollingsworth's (2002) model, as its open-endedness provides a possible pathway where enactment within the classroom (domain of practice) can directly occur from PD (external domain) without being filtered through a teacher’s
knowledge, beliefs and attitudes (personal domain). In response to this problem, Fore, Feldhaus, Sorge, Agarwal, and Varahramyan (2015) proposed a Model of Subjectivation for teacher change following PD. This model was created by modifying Fore's (2013) Cycle of Faith model for how workers develop at a faith-based non-governmental organization in South Africa to represent the process of development for high school STEM teachers. Fore's (2013) define subjectivity as, “the relation of self-comprising one's emergent truths, desires, practices, and perspectives to itself, to others, and to the influence [i.e. power] present in a variety of encounters, whether social, political, economic, or religious.”

Figure 3 Fore, Feldhaus, Sorge, Agarwal, and Varahramyan's (2015) Model of Subjectivation

Fore et al.'s (2015) model prevents the science teacher as a subject from being bypassed en route to PD experiences affecting changes in practice. The Model of Subjectivation assumes that teachers are not raw materials for PD practitioners, and that teachers will often employ a tactical response, informed by their individual subjective components, in order to extract what
they experience from PD could be useful within their own classroom. Fore et al. (2015) explains that construction of these tactics is in an effort to “make due” or “get by” on a daily basis after consideration of the realities of teachers’ professional situations (funding, educational policy, etc.), as well as their students’ situations (parenting, home life, socio-economic status, learning abilities, etc.).

The results of Fore et al.’s (2015) study on STEM teachers receiving PD on nanotechnology revealed that participants filtered their experiences through a subjective lens. For some participants, this included reflecting and modifying new content to fit their classrooms and needs of their students. For example, one teacher was able to take the complex nanotechnology PD content and modify it to become more relevant to their students by relating it to how iPhones charge. For others, the subjective lens the teachers viewed their PD experiences prevented them from believing that the nanotechnology content could be incorporated into their classrooms, citing reasons such as it being too complicated for their students, a lack of resources or funding, a lack of teaching and preparatory time, meeting state standards, or being evaluated by administration. These findings stress the importance of considering how factors outside of PD experiences, such as everyday life, politics, and economics, and parent and student buy-in play into the enactment of new knowledge by teachers. These findings also demonstrate the strength of Fore et al.’s (2015) Model of Subjectivation, as the science teachers in their study were not able to make potential changes in their teaching practices following PD without, first, filtering the new content through their subjective lens. Fore et al.’s (2015) claim that future research on PD and the subjectivation process could yield new insight into the mechanisms of teacher learning and teacher practice. Thus, subjectivation acts as a core influence upon my conceptual change-based theoretical framework.
CHAPTER 2
REVIEW OF THE LITERATURE

2.1 Background and Organization

The intent of this literature review is to showcase the relationships and gaps amongst three interwoven literature domains: Next Generation Science Standards (NGSS), teacher professional development (PD), and teacher change. These domains were selected because the 2013 release of NGSS has prompted the need for PD that will aid science teachers in changing their practices and curricula to the new standards. However, research is lacking regarding the effectiveness of current PD efforts to incline teachers to make NGSS-aligned changes (Shernoff et al., 2017).

According to Creswell (2014), a literature review accomplishes several purposes: it shares with the reader the results of other studies that are closely related to the one being undertaken, it provides a framework for establishing the importance of the study as well as a
benchmark for comparing the results with other findings, and it is shaped from the larger problem to the narrow work issue that leads directly into the methods of a study. This literature review seeks to accomplish these purposes within a set of three topics, organized by section within Figure 4. Section 2.2 contains an introduction to the NGSS, their development, and an explanation of the important new terminology associated with the standards. Section 2.3 details changes that teachers will face when implementing the NGSS, with a focus on the challenges teachers may encounter and their potential needs to confront these challenges. Section 2.4 includes the literature’s consensus characteristics of what constitutes quality PD that can lead to teacher change, as well as current trends in PD. Section 2.5 presents factors that may influence teacher learning and change, according to the literature. The topics in sections 2.4 and 2.5, PD and teacher change, are tightly interwoven and have several areas of overlap. Section 2.6 presents the characteristics and recommended implementation of NGSS-aligned PD. Section 2.7 reveals potential barriers for teacher change following PD, with a focus on implementation of the NGSS, as identified through a synthesis of the literature. These barriers can be both external and internal. Finally, section 2.8 presents the gaps in the literature found through the literature review, as well as challenges I make towards what the literature says about what makes PD effective and whether teachers are willing to change their practices.

It is important to realize that the amount of literature available for each of the three topics is variable. There has been ample research done towards what constitutes quality PD, as well as literature detailing and describing the NGSS. However, literature on teacher change is limited, especially in relation to NGSS-aligned PD teachers receive to induce teacher change. This is due to the relatively young age of the NGSS, being released just a few years ago in 2013. These conditions, in part, dictated my inclusion criteria for this literature review. With the exception of
fundamental papers detailing important history of United States science standards, PD, or teacher change, emphasis was placed on articles published after 2013, as the majority of research past their construction has occurred after this time period. Papers included in this review included one or more of my three topics as a keyword. Some articles contained only one of these keywords, but attention was paid to attempt to select articles with two or all three keywords. Also, articles that included research on or with teachers were only selected if they pertained to practicing PreK-12 teachers, as opposed to preservice teachers. Finally, a priority was placed upon selecting work by top researchers in these fields and the number of times their articles have been cited. These criteria could not be applied to every selected paper, given the young age of NGSS-related research, but efforts were made to include the most important papers in these regards.

2.2 The Next Generation Science Standards (NGSS)

2.2.1 Introduction to NGSS

The NGSS were released in April 2013, succeeding the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy and National Science Education Standards (Cooper, 2013). The *Framework for K-12 Science Education* provided the foundation for NGSS (National Research Council, 2012). The *Framework* is meant to improve upon the previous standards introduced by the National Research Council (National Research Council, 1996) by focusing on learning both science and engineering practices through discovery-based methods (Shernoff et al., 2017). Like the previous standards (National Research Council, 1996), the NGSS entail everything that students should know and be able to do by the time they are high school graduates. However, rather than including a multitude of content topics, the NGSS emphasize a deeper understanding of a smaller number of core concepts
In addition, the NGSS were built to initiate a pedagogical shift from sequentially ordered lessons to having students learn to conduct investigations by questioning phenomena, building hypotheses, and building explanatory models (Shernoff et al., 2017).

The Framework is built around three dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas in science and engineering (McComas and Nouri, 2016). This integration of core ideas, practices, and crosscutting concepts is referred to as three-dimensional learning (Krajcik, Codere, Dahsah, Bayer, and Mun, 2014). The scientific and engineering practices provide the guiding assumptions and organization of the NGSS, allowing students to build theories about the world and design solutions to problems. This section of the standards has eight categories: (1) asking questions and 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) constructing explanations and designing solutions, (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information (National Research Council, 2012). Next, the crosscutting concepts provide the standards’ content and overarching ideas that have applications in all areas of science. The seven crosscutting concepts include (1) patterns, (2) cause and effect, (3) scale, proportion, and quantity, (4) systems and system models, (5) energy and matter, (6) structure and function, (7) stability and change (National Research Council, 2012). Finally, the disciplinary core ideas provide sets of knowledge that have broad importance that increase in depth as students progress through the K-12 grade levels. The four domains of the disciplinary core ideas are (1) physical sciences, (2) life sciences, (3) earth and space sciences, and (4) engineering, technology, and applications of science (National Research Council, 2012).

The NGSS include performance expectations (PEs) that integrate the three dimensions
from the *Framework for K-12 Science Education* (Krajcik et al., 2014). PEs state what students can be assessed on at the end of each grade level, but in contrast with the preceding standards (National Research Council, 1996), they do not act as lesson or unit objectives. For students to gain proficiency in the PEs, the contents of the disciplinary core ideas need to be blended with science and engineering practices and the crosscutting concepts (Krajcik et al., 2014). The demand to teach in this three-dimensional fashion represents a large shift in the landscape of science education and presents many challenges for science teachers. However, Osborne (2014) claims that engaging students in scientific practices will increase the cognitive demand on them in a way that science education has not accomplished in the past, therefore improving the quality of student learning. In addition, the inclusion of engineering practices into the new standards should provide new opportunities for students to better understand how science works (National Academy of Sciences, 2015). These opportunities include building students’ understanding of science ideas by applying them to solve engineering problems, learning key engineering concepts, such as the process of design, and understanding the similarities and differences in how science and engineering practices can be applied (National Academy of Sciences, 2015).

### 2.2.2 Development of the NGSS

Creation of the NGSS started in 2010 and happened in two stages. The first stage was led by the National Research Council, a branch of the National Academy of Sciences, to develop the *Framework for K-12 Science Education* (National Research Council, 2012). The *Framework* was developed by a committee of 18 scientists, science education researchers, and science education standards and policy experts put together by the National Research Council (Bybee, 2014). The second stage was managed by Achieve, an independent nonprofit organization that
works with states to improve standards and assessments (Pruitt, 2014). 26 states contributed teams of K-12 staff, scientists, engineers, employers, and educational leaders to provide multiple reviews and feedback on drafts of the standards to the National Research Council. Eventually, after a 3-year endeavor, the National Academies Press published the final document (National Academies Press, 2013). This second phase also involved the translation of the final PEs for state adoption, done so by 40 writers from across the United States, including K-12 teachers and administrators, higher education faculty, state science supervisors, practicing scientists and engineers, and science researchers (Pruitt, 2014).

2.2.3 The Goal of NGSS

Science standards in the United States have long suffered from being disconnected and presenting too many ideas in a superficial manner, which can leave students with the inability to use those ideas to solve problems and explain phenomena they encounter (Krajcik and Merritt, 2012). The Framework and the NGSS build upon inquiry teaching by engaging students in science and engineering practices, where core ideas are used as evidence in scientific arguments and to support explanations (Huff, 2016). While students will still need to understand general science content, they will now have to apply this content and provide evidence for their claims (Pruitt, 2014). For example, to be considered proficient, students will have to use data with their content knowledge to articulate evidence of a phenomena. It is no longer vital for teachers and textbooks to be the main sources of knowledge for students. Science teachers should, instead, be facilitators that teach students how to situationally use knowledge to better understand and explore the natural world (Cooper, 2013). Therefore, the teacher’s role is to support knowledge-building practices conducive for forming conclusions and arguments, rather than presenting ideas.
through lectures and textbook readings (Reiser, 2013).

The NGSS emphasize putting students in the shoes of scientists and engineers by having them analyze and interpret data, construct models, and revise those models based on arguments from evidence (Cooper, 2013). It is worth noting that attempting to teach students to think like scientists and engage in scientific practices are not necessarily new goals for science educators, but that previous attempts to convey what is particular about the way scientists think and act have not been entirely accurate in their portrayal (Ford, 2015). A classic example of this how the “scientific method” is presented to students as a methodical process that leads to scientific knowledge. In reality, the “scientific method” rarely resembles actual scientific work, as scientists generally do not follow an ordered set of steps to investigate a problem. Despite this variance in how scientists carry out their work, the NGSS seek to provide the common denominator that can capture the essence of their practices.

Even if students may not be able to think and act exactly as scientists do, they can be taught, at least to a basic extent, how to benefit from scientific ways of reasoning and acting that develop into reliable knowledge claims (Ford, 2015). The work of scientists and engineers in the natural world includes many steps and decisions that vary situationally, as well a multitude of repeated attempts (Duschl and Bybee, 2014). It takes scientists and engineers time to ask the right questions and make the appropriate measurements and observations. This is a very different situation than what students encounter with “cookbook” labs that involve step-by-step procedures that lead students to find an answer. These types of activities remove the struggle that is part of the process of doing science or engineering. Without experiencing this struggle, learners get the wrong perceptions of what is involved when obtaining scientific knowledge and
evidence. Thus, a main goal of the Framework and the NGSS is to give students a more authentic experience of the challenges involved in doing science (Duschl and Bybee, 2014).

2.2.4 Scientific Inquiry versus Sciences Practices

One may look at the goal of the NGSS, to simulate the struggle of doing science for students, and wonder why this is not already happening within classrooms in the United States. After all, looking back at the history of science education reform in the US, it appears that this has been a goal all along. Between the 1960s and 1990s, using scientific inquiry as an approach to science teaching became well-supported, with students learning concepts through building an investigatory set of skills (Bybee, 2011). However, the implementation of scientific inquiry into classrooms had mixed results (Banilower et al., 2013). Teachers who use the inquiry approach are unable to simultaneously have students learn science content while also practicing the methods of science. The goal of practicing science is to discover new knowledge about the natural world, while the goal of learning science is to construct an understanding of the existing ideas the our culture has built about the natural world (Osborne, 2014). The Framework and the NGSS seek to expand upon science inquiry, which is simply one form of what the Framework calls “scientific practices” (Bybee, 2011). As the Framework notes, “we use the term ‘practices’ instead of a term such as ‘skills’ to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice” (National Research Council, 2012). The practices give students the opportunity to involve themselves in developing scientific knowledge, while also learning and understanding why we build, evaluate, and refine knowledge as we do (Reiser, Berland, and Kenyon, 2012).
2.3 NGSS and Teacher Change

2.3.1 Challenges for Science Teachers

It is documented that teacher effectiveness is vital to the success of standards-based reform (Fishman, Marx, Best, and Tal, 2003). For science teachers to be effective in teaching the NGSS, there are several curricular and pedagogical changes that they will need to make. One of the key aspects of the Framework and the NGSS is a commitment to coherence and extended instruction (National Research Council, 2012), which involves the creation of a full instructional plan instead of a series of lessons. Teaching content from day-to-day, a common practice with preexisting standards, will negate coherence (Pruitt, 2014). Developing new mindsets and practices in lesson planning will be important for teachers constructing their new NGSS-aligned classrooms.

A vital component of the Framework and the NGSS is the collaborative practice of scientific investigation, questioning, and building explanations (National Research Council, 2012). Unfortunately, there is a good deal of evidence that most science classrooms do not engage students in investigating and explaining (Banilower et al., 2013). In order for students to begin working more like scientists and engineers, they will need to be put into situations where they are encouraged to try repeated attempts and be given time to form appropriate questions (Duschl and Bybee, 2014). This will require a classroom climate where students can feel safe to be wrong, be comfortable asking questions that may have multiple answers, and have discussions that lead to consensus explanations (Reiser et al., 2012).

Research says that deep and accessible subject content knowledge is vital to effective science teaching (Kennedy, 1998), however, content knowledge is not a sufficient condition alone. While teachers may have mastered the science content found and disciplinary core ideas
of the *Framework* and the NGSS, it is documented that most teachers have received little training to develop explicit knowledge of science and engineering practices (Osborne, 2014). Understanding and implementing the new three-dimensional learning style presents, perhaps, the most challenging shift for science teachers. Even teachers who may conceptually understand the curricular and pedagogical shifts involved with NGSS instruction may feel unaware as to how they can make these shifts (Shernoff et al., 2017). Research suggests that the implementation phase, where teachers attempt to apply new learner-centered pedagogical strategies, is where teachers struggle the most (Han, Yalvac, Capraro, and Capraro, 2015). Obviously, science teachers will have several needs in order to feel supported during the transition to teaching the NGSS.

### 2.3.2 Science Teacher Needs

The conceptual shifts and new approach to science education mandated by the NGSS have placed new demands on science teacher learning (Reiser, 2013). Effective professional development (PD) is needed to help teachers design new materials and instructional methods aligned to the NGSS (Shernoff et al., 2017). Appleton and Kindt's (1999) study on elementary teachers found that PD is one of the major factors that teachers perceive as aiding in promotion of effective science instruction. For the NGSS, PD providers will need to supply more than just new ideas for how to approach science teaching (Kennedy, 2016). Research shows that traditional PD programs in which experts simply tell teachers how to implement new classroom practices tend to have little effect on enhancing or changing teachers’ views on how their classrooms operate (Briscoe, 1991). NGSS PD will need to demonstrate a dramatically different approach than what had formerly guided teachers (Kennedy, 2016).
The PD that teachers receive should not translate into instantaneous results, as teacher learning does not happen overnight (Abell, and Lee, 2008). Teachers need time to be able to experiment in their classroom and try out newly developed materials and instructional techniques (Briscoe, 1991). Teachers also need time to engage with their peers in ongoing evaluation of the effectiveness of their approaches, and time to reconsider and revise those goals (National Academy of Sciences, 2015). To expect teachers to completely change their instruction all at once is unrealistic, as teachers will need to take incremental steps. The National Academy of Sciences (2015) states that it will likely take science teachers a 2-3 year period of PD and implementation to be able to make the changes called for in the NGSS. However, teachers will need continued support even past this 2-3 year time period as they refine their instructional approaches to reflect the NGSS vision (Reiser, 2013).

It is documented that teachers are often not being given adequate assistance in applying what they learn in PD to their instruction (Banilower et al., 2013). An important step in implementing the NGSS is to identify staff leadership teams within school districts that will help support ongoing professional learning. These teams should be comprised of teachers and administrators who have showed interest in deepening their expertise with the NGSS (National Academy of Sciences, 2015). These individuals can act as leaders of professional learning communities (PLCs) that work collaboratively other teachers in the district to support teacher learning, sometimes acting as mentors (National Academy of Sciences, 2015). When properly organized, the collegial support that PLCs provide have been demonstrated to be effective in helping teachers focus on their instruction after PD opportunities (Banilower et al., 2013; Sandholtz and Ringstaff, 2016).
The use of PLCs and mentoring must also be accompanied by administrative support (Guskey and Sparks, 2002; Sandholtz and Ringstaff, 2016). Administrators must understand the nature of the changes required by the NGSS and the demands they place on teachers (Krajcik et al., 2014), and thus, administrators should also receive appropriate PD about the NGSS (National Academy of Sciences, 2015). Teachers need time to be able to try new things in their classrooms and build on their knowledge about teaching without the fear of being marked poorly in teacher evaluations (Briscoe, 1991). In addition, administrators must understand that it is unrealistic to assume that teachers will only be spending a day or two on a topic, then move on to another, as was common with the previous standards. Since multiple lessons build coherence towards PEs over time, administrators will need to modify their evaluation schedules and criteria (Krajcik et al., 2014).

In addition to training, time, and collegial and administrative support, teachers need resources to be able to adopt the vision of the Framework and the NGSS. Classroom and school budgets need to account for the purchase of the equipment and supplies that are required to implement the new curriculum (National Academy of Sciences, 2015). Studies by Appleton and Kindt (1999), Fetters, Czerniak, Fish, and Shawberry (2002), (Sandholtz and Ringstaff, 2016) all show that resources, and their management, are vital to promoting teacher self-efficacy and change of practice during times of standards reform. In addition, when new curriculum materials are purchased and adopted, teachers will need time for collaboration to learn to use the new resources effectively (National Academy of Sciences, 2015).
2.4 Effective PD

2.4.1 A Brief Introduction to PD and Effective PD Research

According to Loucks-Horsley and Matsumoto (1999), “anyone cannot teach, and teachers are not born. Students profit from their teachers’ opportunities to learn”. However, looking back to the 1980s, the idea that not all could teach, and that teacher knowledge was critical for improving education, was not widespread. Rather, there was a perception that educational reform could occur by making legislative prescriptions describing exactly how teachers should teach, and that this would allow anyone to teach according the script. By the 1990’s, the failure of these efforts were realized by the policy community, and the literature shows a movement in the research community towards building the capacity of teachers through initial education and ongoing PD (Darling-Hammond, 1995). However, Little (1993) noted that early attempts at PD communicated relatively impoverished views of teachers, teaching, and teacher development. Little (1993) states, “compared with the complexity, subtlety, and uncertainties of the classroom, PD is often a remarkably low-intensity enterprise. It requires little in the way of intellectual struggle or emotional engagement and takes only superficial account of teachers’ histories or circumstances.” This, no doubt, represents a lingering, misinformed perspective that anyone can teach due to the ease of the profession.

In the coming years, many prominent educational researchers continued research into making PD more effective. Haney and Lumpe (1995) claimed that PD should meet the needs of the particular teaching environment, understand the need for community support, implement a long-term plan for action, and construct a vision of improvement. In addition, Haney and Lumpe (1995) proposed a three-stage PD model which includes a planning stage, training stage, and follow-up stage. Darling-Hammond and McLaughlin (1995) claimed that PD research indicated
that teachers need to experience staff development activities over time, see desired instruction modeled, have time to reflect, engage in a common culture of professional inquiry, and experience a support structure for change.

### 2.4.2 Characteristics of Effective PD

Eventually, research in the area of what makes PD effective led to the oft-cited study on effective PD by Garet, Porter, Desimone, Birman, and Yoon (2001). This study analyzed survey data from a national sample of 1027 math and science teachers who participated in the Eisenhower PD Program, and found that the three structural features that aid in setting a positive context for PD include extended study time, collective participation, and emphasis on reform-oriented activities. Additionally, Garet et al. (2001) detailed three core features of PD activities can improve teacher practices, including a focus on subject content knowledge, opportunities for active learning and observation, and coherence with teachers’ previous PD experiences, state standards, and standardized tests. The coming years would build on the work of Garet et al. (2001), with a culmination of studies displaying that effective PD should include the following features: a strong focus on content and curriculum; providing opportunities for rich and active learning; encouragement of collective participation with other teachers; having coherence with teachers’ daily practices and previous PD experiences; having alignment with national, state, and local standards and policies; employing sustained, ongoing learning, while giving teachers sufficient time to learn and develop; and being informed by teacher learning theory (Banilower et al., 2007; Birman, Desimone, Porter, Garet, and Yoon, 2000; Borko, 2004; Desimone, 2009; Desimone, Porter, Garet, Yoon, and Birman, 2002; Garet et al., 2001). The first six of these characteristics are elaborated upon in the coming pages of this section, while the fifth characteristic is elaborated upon in the following section (Chapter 5 – Teacher Learning and
Teacher Change).

Content Focus

The literature contains clear evidence that teacher content knowledge plays a role in raising student achievement (Kanter and Konstantopoulos, 2010). PD programs providing pedagogical content knowledge have been found to be positively rated by teachers (Blank, De las Alas, and Smith, 2008), and can lead to increased teacher knowledge and a positive change in practices (Birman et al., 2000; Desimone, 2009; Desimone et al., 2002; Garet et al., 2001; Kennedy, 1999). In contrast, PD lacking a strong content component has been found to be ineffective in changing teacher practices (Kennedy, 1998). Thus, the consensus is that PD needs to be deeply connected to content (Banilower et al., 2007; Garet et al., 2001). However, while knowledge of the subject itself is essential, such knowledge is not sufficient for teachers take what they’ve learned from PD and turn it into effective instruction (Heller, Daehler, Wong, Shinohara, and Miratrix, 2012). Kennedy (1998) points out PD should place emphasis on how students learn subject matter, and help teachers recognize signs of progress and signs of confusion. This allows teachers to leave the PD with a vision of the subject matter they will teach, what students should be learning about that subject matter, and be able to tell whether their students are learning or not (Kennedy, 1998).

Active Learning

Research has shown that teacher PD is relatively ineffective when it is dominated by direct instruction from experts (Han et al., 2015), and that effective PD involves teachers in active reflection and problem solving (Darling-Hammond and McLaughlin, 1995; Garet et al., 2001). A study by Blank, De las Alas, and Smith (2008) found that in comparison to research on PD in the 1990s, the amount of active roles teachers played in PD sessions during the 2000s
increased substantially.

One example of active learning is the use of rich case accounts of teaching situations, which have been documented to be an effective form of active PD. Borko (2004) pointed out that when teachers analyze and deconstruct rich cases of teaching examples, they are able to better understand the interactions between students and between the teacher and students. The analysis of rich cases of teaching examples can allow teachers to explore what types of activities best give students experience with solving problems, formulating questions, and constructing explanations (Ball and Cohen, 1996; Roth et al., 2011).

Teachers putting themselves in the role of their students is another form of active learning. A study by Jeanpierre, Oberhauser, and Freeman (2005) showed that when teachers experience the learning they want to engage their students in, they are provided with insight into how their students will learn the content. As noted earlier, Kennedy (1998) also advocates for considering how students will learn content. Coaching and mentoring amongst a teaching staff can help teachers plan to implement new curriculum into their classrooms by allowing them to identify potential obstacles they will face in the process, and build strategies to work around them (Luft et al., 2011).

Coaching and mentoring can be particularly helpful when teachers try to implement new material from PD, as they can receive feedback that accounts for their individualized needs (Luft et al., 2011). This sort of prompt, follow-up assistance was found to be vital for educators that struggled to adapt new curriculum in a study by Guskey and Yoon (2009). A more recent development is the increased use of video as a tool for classroom observation and coaching (Desimone and Garet, 2015). Roth et al. (2011) noted that teachers who participate in PD that includes analysis of classroom-based video cases of their teaching, coupled with emphasis on
content, learned more and produced more learning gains for their students than teachers involved only PD on the content alone.

Rushton, Lotter, and Singer (2011) found that, coupled with individual reflection, teachers who were given time to reflect upon their daily experiences with a group of peers helped them to better identify how to incorporate new content into their instruction. Crippen's (2012) study investigated a unique argue-to-learn PD method for improving teacher content knowledge. Despite some teachers shifting their focus from learning content to learning to argue, the study reported group argumentation as an enjoyable, successful method for building teacher content knowledge (Crippen, 2012).

**Collective Participation**

Collective participation involves teachers from the same subject area, building, or district attending PD together (Desimone, 2009). Research has shown that teacher learning experiences should be collaborative and provide opportunities to understand, apply, and reflect upon new content (Garet et al., 2001; Wilson, 2013). Thus, teachers need support in applying ideas to their practice by being given opportunities to discuss the challenges they encounter with their colleagues (Darling-Hammond, 1995; Putnam and Borko, 2000). Additionally, the opportunity to work with other teachers allows teachers to deepen and refine their knowledge of content (Putnam and Borko, 2000). Research has demonstrated that PD is more effective when teachers from similar areas attend it together (Garet et al., 2001), as this allows for conversations that invite positive changes to teacher practices (Birman et al., 2000; Borko, 2004; Loucks-Horsley and Matsumoto, 1999). Collective participation can also lead to the development of professional learning communities that aid in handling curricular changes (Birman et al., 2000). In-school components that follow PD experiences, such as professional learning communities, have been
found to be effective in improving teacher practices (Blank et al., 2008; Tuttle et al., 2016).

Coherence

Coherence is described by Birman et al. (2000) as how PD experiences can be integrated into a program of teacher learning. Learning opportunities for teachers should be connected to teacher practice (Ball and Cohen, 1996; Garet et al., 2001), and thus, PD activities should help teachers plan to implement changes in their classroom, as well as strategize about barriers they will encounter while doing so (Luft et al., 2011). Recognizing the barriers that students face when making sense of new content is one of the main components of a teacher’s knowledge in how to support student learning (Putnam and Borko, 2000), and effective PD achieve coherence by acknowledging these challenges. Research has demonstrated that teachers support PD that emphasizes classroom implementation of practices (Capps, Crawford, and Constas, 2012), but as Banilower et al. (2007) points out, the goal of the PD is important in selecting proper activities that will achieve coherence with teacher practices. For example, a workshop may be effective at building teacher content knowledge, but a study group may be a better option for teacher understanding of how students think about specific topics (Banilower et al., 2007). If coherence with teachers’ learning needs is not a component of the PD, teachers may view the PD opportunity as a waste of their time. It is vital that district leaders and PD practitioners build a menu of learning opportunities that give teachers choices about how to best meet their needs (National Academy of Sciences, 2015).

Alignment with National, State, and Local Standards and Policies

Desimone (2009) notes that PD should be well-aligned with national, state, and local school policies and standards, and a study by Blank et al. (2008) confirmed that almost every PD program found to be effective contained a description of how the program was aligned with state
content standards. In addition, PD has been found to be effective during reform if it is linked to administrative support (Banilower et al., 2007; Guskey and Sparks, 2002). Alignment of PD with all of these various contextual components is critical to influencing teachers to change their practices during standards reform (Darling-Hammond, 1995; Wilson, 2013).

Sufficient Time

Teachers learn at different paces, similar to students. It takes time to process and internalize what is learned during PD experiences, especially if the new concept or strategy challenges a teacher’s prior beliefs (Johnson, 2007). Thus, PD experiences that are of short duration and little follow-up have been found to have little effect on teacher growth and understanding (Loucks-Horsley and Matsumoto, 1999; Spillane, Reiser, and Reimer, 2002). Research on the so called “one-shot workshop”, where teachers are pulled out of their classrooms to be lectured to about technique, has been criticized by virtually everyone interested in improving education (Kennedy, 1998). Since these one-shot workshops are separated from teachers’ working context and classroom, it is often unclear to teachers how any new instructional approaches could be applied (Belland, Burdo, and Gu, 2015). Thus, Lumpe (2007) called for an end to these models of PD, as teachers rarely put what they’d learn into their classrooms, and since, there has been a documented move away from one-shot workshops (Desimone and Garet, 2015).

Blank et al.’s (2008) study showed that the average time teachers spend in PD activities, as well as follow-up work in schools, was significantly greater in the 2000s than in the 1990s. How these PD opportunities achieve sufficient time can vary (Yoon, Duncan, Lee, Scarloss, and Shapley, 2007). Heller, Daehler, Wong, Shinohara, and Miratrix’s (2012) PD program was comprised of eight to ten 3-hour sessions in the summer, while Roth et al.’s (2011) program
consisted of 60 summertime hours and 30 hours spread throughout the school year. Regardless of the number of hours, many studies have shown that PD that is spread out over time tends to be more associated with characteristics of effective PD such as active learning, content focus, and coherence (Birman et al., 2000; Sparks, 2002) In addition, research shows that PD of longer duration is more associated with teachers changing their practices (Banilower et al., 2007; Boyle, While, and Boyle, 2004; Desimone, 2009).

2.4.3 Current Trends in PD

The research of Desimone and Garet (2015) has added modern trends to the list of long-standing characteristics of what makes PD effective. Their study found that teachers vary in response to the same PD, due to different levels of experience in content knowledge and from various classroom contexts. This implies that PD should be differentiated to fit individual teacher needs. However, the increased commonality of administrator and teacher mobility (i.e. changing schools) has placed a need for PD to be applicable from district to district. Mobility places PD practitioners in a challenging position, as PD must not only be tailored to the individual, but also applicable in multiple employment scenarios. Building on the characteristic of coherence, PD needs to be more deliberately aligned with teacher lessons so that teachers can more easily integrate the knowledge they acquire into their instruction once they return to the classroom. Finally, with the increasing trend of linking PD to teacher evaluations, PD programs have been shown to be more effective when they are not only aligned with national, state, and local standards, but also with district leadership priorities.

The work of Banilower et al. (2013) has given insight into the kinds of PD experiences that have been most common for teachers between 2010-2013. Their study of math and science
teachers revealed that only around one third of teachers of any grade level had taken formal courses for college credits or attended national, state, regional, or professional association conferences or meetings. Workshops and professional learning communities were found to be the most prevalent form of PD. 84%-92% of surveyed teachers for any grade level reported having participated in workshops within the last three years, and roughly 75% of high school and middle school teachers engage in PLCs. Elementary teachers, however, were found to be less likely to have participated in PD, and far less likely to have engaged in PLCs or mentoring/coaching. Additionally, while teachers of all grade levels did not report their PD experiences as a waste of time, the duration of PD hours was found to be generally very low, especially for elementary teachers. Around one third of middle school and high school teachers reported having over 35 hours of PD in the last three years, and this figure dropped to only 4-11% for elementary teachers.

The trends presented here indicate a shift away from one-shot PD experiences, such as conferences or meetings, which is consistent with the research of Desimone and Garet (2015). Additionally, Banilower et al. (2013) revealed a shift from costly PD (college courses) to less expensive PD (workshops and PLCs). Unfortunately, while Blank et al.'s (2008) study showed an increase in the average time teachers spend in PD, the current number of hours teachers spend in PD is still low, especially for elementary teachers. This trend is unsettling given that PD of longer duration has been documented to be most effective at changing teacher practices (Banilower et al., 2007; Boyle et al., 2004; Desimone, 2009).
2.5 Teacher Learning and Teacher Change

2.5.1 A Brief Introduction to Teacher Learning and Teacher Change

Teachers have often been targets of reform, but have historically exerted little control over the PD they receive. PD in the United States can come from a wide variety of sources, including freelance consultants, intermediate and state agencies, professional associations, universities, and from within schools and school districts (Sykes, 1996). Teachers have had to sort through the many competing programs and ideas from these sources during periods of reform, all of which can represent a substantial departure from their prior experience, beliefs, and practices (Little, 1993). The success of any reform agenda relies upon teachers’ ability to learn new skills and perspectives while unlearning the practices and beliefs about their instruction that they previously held (Darling-Hammond and McLaughlin, 1995).

However, despite more attention being paid to the importance of PD driving reform in the 1990s, few occasions for this sort of learning and subsequent change in practice existed (Darling-Hammond and McLaughlin, 1995). Briscoe (1991) pointed out the common occurrence of teachers returning to the classroom in the fall, following summer PD sessions, feeling ready to implement newly learned techniques. However, teachers would generally find themselves falling back into their old habits of teaching the same way they had before, utilizing some of the new materials, and adapting some of them to fit their traditional methods. These teachers, who have been asked to incorporate new features of their teaching, simply modified the features to fit within their preexisting system, rather than changing the system itself. On the surface, some things appeared be different, but the fundamental nature of their instruction remained intact, leading to anticipated improvements in student learning that failed to materialize (Stigler, 2000).
2.5.2. Factors that Affect Teacher Change

While there is much research that exists on characteristics of effective PD, there is substantially less literature that focuses on teacher learning and teacher change. Teacher change of practice, or lack thereof, has been described by Smylie (1988) as being rooted in self-perceptions based on experiences within the classroom and with colleagues. In the late 1990s, Loucks-Horsley and Matsumoto (1999) produced a list of themes in regard to how teachers learn, which include prior beliefs affecting what they learn, time to learn and unlearn, strong content knowledge, knowledge of how children think, and reflecting and analyzing upon practices. A decade later, Desimone (2009) presented a list of six factors that influence teacher change, including the amount of experience a teacher has; the motivation to attend PD; working conditions; teacher self-efficacy; school culture; and teacher beliefs.

Teacher Experience

The number of years of teaching experience in the classroom is a crucial factor in considering whether PD will influence teacher change (Whitworth and Chiu, 2015). Luft's (2001) study showed that while comparing a beginning group of teachers to an experienced group of teachers that had received the same PD, beginning teachers changed their beliefs more than their practices and the experienced group changed their practices more than their beliefs. Additionally, years of teaching experience can affect what type of PD teachers believe is relevant. Lewis et al. (1999) showed that teachers in the early stages of their careers tend to think PD revolving around classroom management and new pedagogy is most important, while veteran teachers believed PD that advanced content and pedagogical knowledge was most valuable. This indicates that the number of years of teaching experience a teacher has can affect whether a particular PD program induces teacher change.
Motivation to Attend PD

The motivation a teacher may have to attend PD can widely vary. An increase in salary, renewal of a certificate or accreditation, career mobility, increasing knowledge, or learning new skills could all be potential reasons to attend PD (Stout and Runion, 1996). School-mandated curricula and PD tend to hinder teacher change (Appleton and Kindt, 1999; Richardson, 1998), but many teachers seek out PD on their own in an effort to seek out innovative strategies to enhance student learning (Briscoe, 1991; Smylie, 1988). Additionally, a study by Smith, Hofer, Gillespie, Solomon, and Rowe (2003) showed that teachers with a high level of motivation to attend PD sessions are more likely to change following their participation.

Working Conditions

Teacher satisfaction levels regarding their workplace can have an important impact on their willingness to learn and change their practice. The amount of prep time teachers receive, available resources, support from administration, and other school situational factors can limit the degree a teacher is willing to change, as well as the permanence of any changes (Smith and Gillespie, 2007). In addition, other working conditions such as job status (full or part time), salary level, and benefits can all have an effect on teacher performance and turnover (Ingersoll and Smith, 2003). Teachers who are not committed to a long-term career in the educational field will have little interest in changing their practices.

Self-Efficacy

Teacher self-efficacy is a belief in one’s own capabilities to perform effectively (Lotter, Smiley, Thompson, and Dickenson, 2016). In Haney, Lumpe, Czerniak, and Egan's (2002) study of elementary teachers, high-quality lessons were correlated with teachers’ high self-efficacy. Lotter et al.’s (2016) study found quality PD can raise the skills of teachers with low self-efficacy.
to the same level of teachers with high self-efficacy. Self-efficacy can play a heavy role in teacher change. Teachers that have stronger self-efficacy are more likely to change their practices, regardless of how far along they are in their teaching career (Smylie, 1988). The act of attempting to implement new practices and finding success has been shown to increase self-efficacy (Stein and Wang, 1988). Thus, self-efficacy is interwoven amongst lesson performance, PD, and teacher change.

School Culture

School culture plays a role in teacher change in classroom practices. A case study by McGinnis, Parker, and Graeber (2004) showed that school culture was a main factor in influencing whether teachers would continue teaching and attempt to grow professionally. This study also found that schools that promoted a culture of collegiality showed increased effectiveness in changing teacher practice following PD opportunities (McGinnis et al., 2004), and increased collaboration within a school can result in additional teachers being open to adopting new practices.

Beliefs

Teacher beliefs are possibly the most important factor that can affect teacher change in practice and beliefs (Guskey, 1986). Beliefs be labeled as a variety of aliases, including attitudes, opinions, ideologies, dispositions, or theories (Pajares, 1992). If changes in practice are to occur, the reform effort must address any teacher beliefs that are in opposition reform goals (Rushton et al., 2011). If beliefs are ignored, teachers may close themselves off to learning and reject new ideas that conflict with their current ideas, as change is as much about emotions as it is about knowledge and skills (Timperley, 2008). Putnam and Borko (2000) note that unless learning opportunities for teachers consider what they call a teacher’s “situated perspective”, where
knowing and learning are situated in a teacher’s physical and social context, teachers will consider the learning experience too far removed from their day-to-day work to have a meaningful impact. Without the engagement of their current understandings and beliefs, teachers will often dismiss new strategies as unrealistic or irrelevant (Timperley, 2008).

2.6 NGSS PD

2.6.1 Characteristics of NGSS PD

When the National Science Education Standards (National Research Council, 1996) were adapted, guidelines for effective PD to implement the standards were also put forth. Some of the guidelines aligned with general characteristics of quality PD presented by Garet et al. (2001), including coherence and emphasis on content knowledge (National Research Council, 1996), but some of the characteristics were more specific to science teaching. For example, the guidelines stated that PD should aid science teachers in developing content knowledge through inquiry-based methods, as well as having teachers actively investigate phenomena, interpret results, and engage in sense-making practices (Luft, 2001). The goal of these PD programs were to help teachers not only develop science content knowledge, but also apply their knowing of content to their classroom practices (Fishman et al., 2003). The guidelines for the NGSS PD build upon the characteristics of the National Science Education Standards. Active learning, sufficient duration of PD sessions, opportunities for feedback and reflection are all components of NGSS PD (Roth et al., 2011), as well as being contextualized and supported over long periods of time (Desimone, 2009). As Sandholtz and Ringstaff’s (2016) study pointed out, we are still in the process of identifying the major contextual factors that influence long-term changes in teacher practice, as
well as the sustainability of those changes. However, it is evident that ongoing support is vital to the longevity of PD outcomes in science (Sandholtz and Ringstaff, 2016).

2.6.2 Implementation of NGSS PD

Shymansky et al. (1997) note that when constructing ideas in science, alternative interpretations of the same evidence are possible, and those alternatives must be collaboratively evaluated to come to a consensus conclusion. This constructivist view has shaped both what should be taught and how it should be taught when the Framework and NGSS were crafted. The NGSS will require teachers to make changes in their classroom to allow students to experience more authentic science experiences (Reiser, 2013). The educational and research communities widely embrace the active, discovery-based approach within the NGSS (Shernoff et al., 2017), but their implementation poses challenges. Penuel, Harris, and Debarger (2017) list the strategies for implementation of the NGSS as, “provide high-quality curriculum materials to teachers and students, provide PD focused on performance expectations for students linked to classroom teaching and sustained over time, monitor and support implementation, and develop and use assessments that measure knowledge-in-use.” According to the National Academy of Sciences (2015), the PD models that Penuel, Harris, and Debarger (2017) describe should be designed to not only have teachers think about the science concepts in the NGSS, but also how students think and learn about science. Additionally, NGSS PD should go beyond presentation of new ideas and strategies. Teachers need opportunities to analyze and discuss model examples of classroom interactions that reflect teaching a particular issue. These model examples should include components of the NGSS that may be foreign to teachers, such as helping students learn to develop and defend arguments based on evidence or facilitating engineering design (National Academy of Sciences, 2015). Through the investigation of model examples, teachers can work
together to debate their interpretations and better understand the importance of collaboration for their students.

PD of this nature will require teacher educators to have some sort of plan for the structure they are hoping to build, as having teachers practice without clear, well-specified goals will provide little guidance for classroom implementation (Osborne, 2014). Desimone (2009) proposed a four-step operational theory of how professional development influences teachers, their instructional practice, and student learning. The four steps in the theory include: teachers participating in effective PD; teachers participation increasing their knowledge/skills or changing their attitudes/beliefs; teachers adapting their instructional practices; and teachers making changes in instructional practices to promote student learning. Such changes in practice require a sufficient investment of time for teachers to tackle new ideas and make step-by-step progress in understanding and applying the new ideas (National Academy of Sciences, 2015). Pruitt (2014) noted that as of 2014, the states who had adopted the NGSS were planning on a three to four-year timeline for training teachers and administrators and develop and implement quality materials. However, this timeline only refers to initial teacher training. The National Academy of Sciences (2015) noted that it may be as many as 10 years before the majority of students arrive in the high school setting with the necessary training for the new curriculum that teachers are expected to implement. Thus, training will need to extend well past the three to four-year timeline, as teachers will need to continually refine their approaches and expectations of what students can do (National Academy of Sciences, 2015). The literature provides some models available to aid teachers in this process, including Krajcik et al.'s (2014) 10-step process of bundling PEs to build lessons, Rinehart, Duncan, and Chinn's (2014) model-based argumentation system, Duschl and Bybee's (2014) 5-dimensional model of planning and carrying out
investigations, and Shernoff, Sinha, Bressler, and Schultz's (2017) problem-based approach to incorporating the NGSS. Unfortunately, good models of curricular units aligned with to the NGSS and good PD designed to assist teachers in creating them are still in relatively short supply (Shernoff et al., 2017).

2.7 Barriers that Affect Teacher Change and the Implementation of New Standards

Changing instructional practices is not something that teachers accomplish easily or without conflict (Johnson, 2007). Which internal and external contextual factors exert the most significant influence of teacher concerns, mastery, and patterns of classroom innovation has been historically uncertain (S. E. Anderson, 1997). Johnson's (2006) study on effective PD and barriers teachers face in reform revealed that science teachers lack time for collaboration, administrative support, and resources. Banilower et al.'s (2013) national survey on math and science teachers found that the factors that a majority of schools perceive as inhibiting science instruction included time for planning, time for PD, student abilities, and testing/accountability policies for both district and state. A review of the literature includes the barriers listed in Johnson's (2006) and Banilower et al.'s (2013) studies, along with several others. Given the significantly different challenges that teachers will face in implementing the NGSS than in the past (Shernoff et al., 2017), research is needed as to specifically which of these barriers have the most impact on current teachers, or if there are new barriers that are yet to be determined.
2.8 External Barriers to Teacher Change

2.8.1 PD-Related Issues

Time

Johnson's (2006) study found that teachers lack time for collaboration at the school and department level due to lack of common planning time, which forced teachers to use their lunches, come to school early, or stay late to meet with other teachers. This puts added stress upon teachers to find time to make copies and plan for class lessons and laboratories. Banilower et al.'s (2013) study also found that inadequate time for PD was associated with inhibiting effective science instruction. There is also evidence that the amount of time that teachers spend in PD is not adequate, and that teachers do not have time to implement information learned in PD. Shernoff et al. (2017) noted that some teachers participating in NGSS PD sessions in their study suggested that a 4-day workshop was not adequate to meet their needs, and thus PD of greater duration was recommended. Additionally, participants in Fore, Feldhaus, Sorge, Agarwal, and Varahramyan's (2015) study noted that frequent changes in school schedules and cancellations of classes due to poor weather forced some teachers to modify their course delivery, leaving little time to consider how to integrate information from their summer PD experiences.

PD that Meets Individual Needs

The PD needs of elementary, middle, and high school science teachers are different, and thus, the National Academy of Sciences (2015) suggest planning separately for development of each grade band. Additionally, teachers’ PD needs may be affected by their level of teaching experience. In a study by Zhang, Parker, Koehler, and Eberhardt (2015), when compared to
experienced teachers, beginning teachers reported greater needs for PD that improved their content knowledge, understanding of student learning, curriculum building, and assessment strategies. However, the results of PD efforts have been traditionally disappointing, with teachers finding their PD experiences as irrelevant to their work in classrooms and misaligned with their improvement needs (Borko, 2004). Given that teachers commonly complain that PD is a waste of their time, National Academy of Sciences (2015) call district leaders to ensure that teachers’ PD opportunities are structured to make effective use of teachers’ time and offer choices for how to be meet their PD needs.

*The Honeymoon Period*

Rushton, Lotter, and Singer (2011) state that the question that still remains unanswered is the extent to which teachers continue to incorporate elements from PD experiences into their classrooms after PD has ended. They note that it is possible that teachers experience a “honeymoon” period, during which teachers experience enthusiasm to implement new ideas, followed by teachers returning to their old ways after some time (Rushton et al., 2011). This supports the need for studies of longer duration on the effects of PD on teacher change, as called for by Lawless and Pellegrino (2007) and Sandholtz and Ringstaff (2016).

### 2.8.2 Collegial Issues

*Collegial Support*

Collegial support and teacher collaboration can contribute to how teachers use the strategies learned in PD experiences, but there is evidence that teachers receive varying levels of support in this manner from district to district, and that collegial support and collaboration during PD may not extend past the program itself (Sandholtz and Ringstaff, 2016). This begs the
question as to whether teachers who receive PD become proficient enough with new practices to serve as professional developers of their school and district colleagues, or leaders of PLCs, so that the PD effort is extended past the initial cohort (Rushton et al., 2011). Additional research is needed in regard to how PD extends past its application, and the challenges that ensue in the process, while teachers attempt to move past traditional approaches.

**New Teacher Education and Support**

A study by Hanuscin and Zangori (2016) on prospective teachers understanding the NGSS revealed that while many participants increased their understanding the Science Practices and Disciplinary Core Ideas within the new standards, many had trouble comprehending Crosscutting Concepts. This signals a need for research on how teacher educators build the knowledge and beliefs for teachers who are about to enter the profession. Additionally, the literature contains evidence that many beginning science teachers are not trained in learning to teach science, and there is a lack of research on how science teacher educators continue to work with new science teachers (Jian Wang, Odell, and Schwille, 2008). Luft et al. (2011) suggest that this gap in the literature may stem from a lack of resources, or possibly the assumption that the school districts that employ new teachers are responsible for their development after hire. The potential of new science teachers, who are generally more malleable during their early years, will continue to be unrealized without research upon this population.

**Teacher Turnover**

Educational reforms have changed the educational landscape, which has placed professional and economic burdens upon schools and teachers, including PD, to keep up with content and pedagogical changes (Fore et al., 2015). The aftermath of new educational policies has contributed to an “exodus” amongst qualified educators from the teaching profession.
(Keigher, 2010; Watlington, Shockley, Guglielmino, and Felsher, 2010). Sandholtz and Ringstaff's (2016) study should that teachers in school with high rates of principal turnover experienced greater challenges in maintaining science instruction over time, and that collegial support is negatively affected when teachers retire, leave the teaching profession, move to different schools, or change grade levels. The aftermath of educational policy has created a state of metamorphosis for science teacher preparation and PD (Fore et al., 2015).

2.8.3 Political Barriers

Political barriers have implications for school and district administration, as teachers need support in the form of PD that address technical barriers (Johnson, 2006). Lederman and Lederman (2013) point out that the NGSS is an ambitious vision for K-12 science education, and will require careful consideration of the specific elements of PD that is needed for current and future science teachers. However, Lederman and Lederman (2013) science teacher education is constantly under attack by policy makers and stakeholders. Fore et al.'s (2015) study revealed several challenges that teachers face that strained their ability to considering implementation of new content learned through PD. Many school districts expect teachers to cater their instruction to rigid pacing guides that detail the specific order and curriculum that teachers must use to align with specific standards. Alignment to these standards was directly linked to teacher evaluations; and gaining an “effective” or “ineffective” label was used to determine whether a teacher deserves a raise in salary. Additionally, teachers expressed they were only able to find time to attempt to implement new content after they ensure that their students are prepared for standardized tests. Kennedy (2016) notes that in addition to adhering to school, state, and national policy, teachers experience a “noisy” educational system where they are surrounded by
multiple and conflicting messages. For example, teachers are expected to treat all students
equally, yet respond to each child’s unique needs; be strict and forgiving at the same time; and be
intellectually demanding but leave no child behind. If too much emphasis is placed on any of
these ideals, teachers may compromise their effectiveness in another.

2.8.4 Student Preparedness

Furtak, Seidel, Iverson, and Briggs (2012) note that the adoption of the NGSS will
require time and support for students to develop increasingly sophisticated explanations of
phenomena, which will require a shift in the classroom culture. An important implication of this
shift is for schools to consider how to support students in higher grades who, in early years of
implementation of the NGSS, may have not had prior learning experiences necessary to meet the
expectations of the new standards (National Academy of Sciences, 2015). Krajcik and Merritt,
(2012) express enthusiasm for the potential of the types of students that the NGSS could
produce, by stating, “imagine the type of student who emerges from 12th-grade science
education after repeatedly experiencing instruction since elementary school that supported them
in constructing and revising models to explain phenomena! These students will form a different
breed of high school graduates who view science as an “effective method of inquiry” and who
will serve as productive 21st-century citizens to create a sustainable planet.” However, it will
take many years before we begin producing students who have experienced the NGSS for a full
12-year period. This presents a major challenge for teachers, as from year to year, their students
will enter with variable levels of exposure to the NGSS-style of learning (National Academy of
Sciences, 2015). It may be difficult for some teachers to resist the urge to revert back to safe,
traditional science teaching methods that students have been accustomed to if teachers observe
student resistance to the NGSS.

### 2.8.5 Resources and Finances

Available resources for teachers affect both initial implementation and ongoing use of reform-based teaching strategies (Sandholtz and Ringstaff, 2016). Teachers who participated in Johnson's (2006) study showed that many science teachers lacked resources such as physical space, sinks, equipment, budget for consumable materials, and adequate class time needed to implement changes in their curriculum. In Fetters, Czerniak, Fish, and Shawberry's (2002) study of science teachers piloting a new curriculum that incorporated science kits, teachers reported management of resources as being a source of frustration during attempts at implementation. Because of a limited amount of resources, equipment needed to be rotated, and this created problems amongst teachers with distribution, timing, and replacement of materials (Fetters et al., 2002). Consideration of funds and resources is particularly important for implementation of the NGSS in urban schools, which often face the challenge of limited resources, as noted by Lee, Miller, and Januszyk (2014). Some studies have demonstrated teachers finding ways around a lack of resources. One science teacher in Fore et al.'s (2015) study who was able to incorporate learned PD content by adapting it into a low-cost PowerPoint presentation to overcome a lack of resources. However, simple solutions such as this will not always be an option for science teachers when implementing the NGSS.

Inadequate science education funding extends past resources and learning experiences for students, as it also affects the availability and quality of PD experiences for teachers. The National Academy of Sciences (2015) suggest that if schools find themselves with inadequate funds for PD, they should seek partnerships with other school districts, science-rich
organizations, or external funders, but these sorts of resources may not be available for all schools. Lawless and Pellegrino (2007) note that while it has been documented that finances play a heavy influence on school districts’ ability to administer science teacher PD, none of their reviewed studies on PD programs included a cost-benefit analysis or a feasibility study for scaling a PD intervention on a national level. Kennedy (1998) points out that even if a particular PD model is more effective than another, it may be logical to choose the option that is less expensive to run. Producing PD that is feasible to be widely-implemented will require research into which PD programs are simultaneously effective in improving science education, but cost-effective as well (Banilower et al., 2007).

2.9 Internal Barriers to Teacher Change

2.9.1 Teacher Preparedness

The National Academy of Sciences (2015) state that there are many approaches to science instruction that could be consistent with the vision of the Framework and the NGSS, but as Shernoff et al.’s (2017) study showed, the immense complexity and adaptability of the NGSS can be overwhelming for teachers. While many teachers may be able to comprehend the shifts necessary to align with the NGSS, it is documented in the literature that teachers struggle most during the implementation phase during educational reform (Han et al., 2015). Teacher preparedness and self-efficacy can greatly influence the success of standards reform (Haney and Lumpe, 1995), however, recent studies have revealed alarming statistics in regard to teacher preparedness. Banilower et al. (2013) found that only 39% of surveyed elementary teachers felt well prepared to teach science, and that many early childhood educators do not teach science using inquiry. This is particularly alarming given that the NGSS seek to go beyond scientific
inquiry, a key component of the 1990s standards (Bybee, 2011). If many elementary teachers do not feel prepared to teach science through inquiry, it will be a tall order to expect them to make pedagogical shifts that build upon inquiry as a base.

The problem of preparedness extends past elementary science teachers. The Framework and the NGSS incorporate engineering practices into science classrooms, but Banilower et al.’s (2013) study showed that fewer than 10% of middle and high school teachers feel very well prepared to teach engineering concepts. It is reasoned that this is likely because of a lack of college coursework in engineering, and Banilower et al. (2013) note the need for engineering-specific PD. However, Shernoff, Sinha, Bressler, and Schultz (2017) observed that even after participating in NGSS PD sessions, teachers’ knowledge of engineering practices were not developed to where they could create NGSS-aligned engineering curricula. Bybee (2011) acknowledges that while incorporation of engineering practices into curriculum will be a significant challenge for teachers, their relationship to science practices is complimentary. However, McComas and Nouri (2016) worry that blending science and engineering could have potentially negative consequences. Part of their reasoning is that science and engineering have different goals and methods, but only the most sophisticated teachers and learners may be aware of this (McComas and Nouri, 2016). Lederman and Lederman (2013) add to the list of concerns with engineering practices by pointing out that engineers and scientists will often use different terminology for the same concepts, and that while activities that incorporate science and engineering practices have existed in classrooms for years, the distinction between them has not been made clear for teachers. While there is a clear call for engineering-specific PD to help address these issues for science teachers (Banilower et al., 2013), research on engineering PD within the literature is lacking. PD programs have emerged to assist science teachers in better
understanding engineering practices, there is little documentation of their approaches or effects (Daugherty, 2009).

2.9.2 Misunderstanding NGSS

Rodriguez (2015) points out that without prompt and direct transformative action, teachers may view the NGSS as another educational fad ride, full of buzzwords and political slogans that don’t deliver on their promises to advance science learning. Given the history of science education reform in the US, it is feasible for teachers to misidentify the NGSS as another swing of the pendulum that will be replaced in the coming years by another set of standards, such as the previous standards (National Research Council, 1996) were. However, this mindset may be due to misconceptions associated with the NGSS. Bybee (2013) points out that some teachers may think that if a curriculum address content associated with the NGSS (i.e. life, Earth and space, and physical science), then it is “doing NGSS”. However, content alone only touches upon one of the dimensions of the three-dimensional learning approach found within the Framework and the NGSS. Huff (2016) and the National Academy of Sciences (2015) both note that while some existing activities may appear to be aligned with the NGSS because they are “hands on”, they often miss the mark because they do not address building and testing explanatory ideas. Spillane, Reiser, and Reimer (2002) note that teachers who view the NGSS through the lens of their current practices, such as a physics teacher considering their students as already learning engineering by conducting egg-drop contests, may underestimate the need for changes in their practices.

As Reiser (2013) points out, teachers may see the science and engineering practices as equivalent to “inquiry”, with just a new name. This lack of understanding and differentiation of
vocabulary extends into science education literature. Tuttle et al.’s (2016) study on an NGSS-aligned PD model for early childhood teachers contains several references to developing teachers’ ability to teach science though inquiry, but several other works within the literature note that science inquiry is different from the scientific and engineering practices within the *Framework* and the NGSS. Bybee (2011) points out that teaching through science inquiry has not done an adequate job of simulating the struggle of doing science, and Duncan and Cavera (2015) note that the use of the word “practices” is meant to signal a shift in how we view inquiry-based teaching and learning, and that many inquiry-based lessons do not meet the intent of the *Framework* or the NGSS. Additionally, any confusion over these differences in terminology can be easily addressed without an investigation into the literature. A simple trip to the NGSS homepage’s explanation of three-dimensional learning will present the following statement: “The NRC uses the term practices instead of a term like “skills” to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice. Part of the NRC’s intent is to better explain and extend what is meant by “inquiry” in science and the range of cognitive, social, and physical practices that it requires. Although engineering design is similar to scientific inquiry, there are significant differences. For example, scientific inquiry involves the formulation of a question that can be answered through investigation, while engineering design involves the formulation of a problem that can be solved through design. Strengthening the engineering aspects of the NGSS will clarify for students the relevance of science, technology, engineering and mathematics (the four STEM fields) to everyday life” (National Academies Press, 2013). Regardless, if published scholars do not agree on the terminology and intentions of the NGSS, it is reasonable to expect that these misunderstandings extend to teachers, administrators, and possibly even PD practitioners. This
may contribute to the myth that science teachers’ existing practices are aligned with the NGSS, as pointed out by Bybee (2013).

2.9.3 Internal Resistance to Adopting New Materials and Mindsets

Most teachers participating in PD will have already developed their materials, practices, found ways to balance their many competing challenges and ideals, and formed habitual methods for classroom management and organization (Kennedy, 2016). The National Academy of Sciences (2015) acknowledge that science teachers already have this repertoire of ideas and activities, and that some could still be useful, but suggest that teachers carefully reexamine their materials with the possibilities for redesign or elimination. Duncan and Cavera (2015) take this statement even further by stating that because the NGSS represent such a markedly different way of teaching science, existing lessons cannot be used by next-generation teachers. Kennedy (2016) seconds this notion by claiming the new ideas offered by PD for the NGSS will require science teachers to not only adopt new practices, but completely abandon their prior approach.

Johnson’s (2009) study on teacher beliefs and experiences that allow teachers to become effective (or not) after PD gives unique insight into how teachers’ internal predispositions and beliefs affect teacher change. The two effective teachers presented in the study were motivated by feeling they possessed the skills needed to make changes, positively impact student learning, and avoid teaching to the test. The ineffective teacher presented in the study chose not to make changes because of their own personal experiences as a learner that they could not overcome, and a heavy influence from the need to drill and practice for state assessments. In measurements of student achievement, the effective teachers’ students scored higher on state assessments by their use of the investigation-based teaching style they learned through PD. Johnson (2009) notes
that the PD administered to these teachers was only successful in improving the practices of the teachers who were predisposed to accept change. For the teacher who was predisposed to be resistant to change, the PD had little effect. Johnson (2009) points out that this is because the PD did not place the teachers in a scenario that forced them to examine their current practices along with a more effective mode of instruction. Thus, NGSS PD programs will only be effective if they are cognizant and intentional in recognizing what teachers bring into PD in terms of existing practices, predispositions, and beliefs.

2.10 Gaps in the Literature

2.10.1 Lack of Research on Effectiveness of PD Programs

Historically, research on PD has shown a general lack of effectiveness in teacher enhancement (Guskey, 1986). Researching strategies to improve science teacher PD could clearly benefit its effect on teachers, but studies that give insight into why some PD works and some does not are not widespread. Since PD can vary in so many ways, it can be difficult to draw conclusions about what factors influence success or failure of PD efforts (Desimone and Garet, 2015). The features of PD can vary across different types of programs, content areas, and grade levels, and many studies of PD overlook this complexity (Scher and O’Reilly, 2009). Additionally, PD coming from multiple providers and sources can hinder coherence, leading to teachers to fragmented experiences with little continuity. Desimone and Garet (2015) call for identification and manipulation of very specific features of PD in order to isolate and study their influence.

For science teacher PD, the lack of published research in the effectiveness of PD programs in science and engineering design has inhibited teacher progress in NGSS
implementation (Tuttle et al., 2016). For the studies that do exist on improving science teacher PD, the results rarely reach the classroom. Vázquez-Bernal et al. (2011) claim that this is because many studies are typically performed on teachers rather than by and with teachers. More studies should seek to work with teachers in researching what they feel is most beneficial in meeting their professional needs. Additionally, the literature that does exist on effective science teacher PD tends to focus on late elementary or secondary teachers and not on early elementary teachers (Capps et al., 2012). Thus, a pressing need has developed for studies on science teacher PD that include early childhood educators (Tuttle et al., 2016).

2.10.2 Lack of Research on Teacher Learning

Scher and O’Reilly (2009) note that the notion that teachers, much like students, are learners is relatively new and not well researched. This is largely because evaluations of the effects of PD on teacher learning do not collect immediate, intermediate, and long-term data. Collection of such data could show how PD programs affect student learning and inform PD providers how revise their efforts. Instead, research involving PD is typically less concerned with teacher learning and more concerned with best practice (Fore et al., 2015). While the literature shows that research into best practice is necessary (Ball and Cohen, 1996; Desimone, 2009; Garet et al., 2001; Putnam and Borko, 2000), solely focusing on this may lead to authors of PD programs forming program outcomes that do not include the complexity and sociocultural embeddedness of teacher learning (Opfer and Pedder, 2011). Sparks and Loucks-Horsley (1989) and Fore et al. (2015) both note that PD content is filtered through teacher subjectivities that are formed by previous teaching and learning experiences. However, PD learning models continually downplay the role of these subjectivities, leading to misrepresentations of teacher
learning and change (Opfer and Pedder, 2011). For science teachers in particular, literature is lacking regarding their learning process, knowledge, and abilities to integrate PD experiences into their classrooms (Lederman and Lederman, 2013). Some more recent PD models have attempted to address this issue, such as Lotter, Smiley, Thompson, and Dickenson's (2016) ‘science teacher as learner’ model that has teachers actively participating in their learning, but there is still little consensus about how modern PD activities work in fostering teacher learning and altering teaching practice (Kennedy, 2016; Walter and Kautz, 2015). Additionally, it was noted by Borko (2004) that literature seeking to explain how teachers and students benefit from professional learning is limited, and insights into how teacher learning is related to student achievement are still scarce (H. Lee, Longhurst, and Campbell, 2017).

2.10.3 Lack of Research on Teacher Change

Both historically and modernly, very little evidence is available linking PD programs and effective changes in teacher practice (Scher and O’Reilly, 2009; Smylie, 1988). Stein and Wang (1988) pointed out that while teachers may be able to implement new innovations during times of reform, PD programs failed to incorporate research on motivational factors related to teacher change. Haney, Czerniak, and Lumpe (1996) pointed out the need for qualitative case studies on the change process in teacher beliefs and its relationship to classroom practices, but a literature review by Lawless and Pellegrino (2007) showed that studies on PD continue to focus on its design and not on the pedagogical changes that transpire with teachers. This emphasis in the literature on PD design is echoed by Park Rogers et al. (2010), and again, Marra et al. (2009) call for research between PD and its impact on teacher knowledge and behaviors. Recently, Belland et al. (2015) suggested that interviews and observations of teachers could give insight into what
types of PD strategies teachers found useful and how they perceived their practice has been improved.

In regard to NGSS PD for science teachers, the literature contains many suggestions for what would make the PD effective. Rodriguez (2015) notes the NGSS PD should focus on moving teachers away from their traditional teaching habits, which he refers to as “the safest practices”, and Lotter et al. (2016) points out that NGSS PD should target changing teacher practices by considering how teacher beliefs and actions influence the outcomes of PD. However, the literature is sorely lacking studies on how NGSS PD has influenced changes in science teacher practice. One example that does exist is recent study by Shernoff et al. (2017), which noted that after the administration of their project-based PD model, participating teachers made significant pedagogical and curricular shifts to align with the NGSS. However, the teachers’ application of their new knowledge to writing curriculum varied in quality. Thus, Shernoff et al. (2017) suggest additional research is needed on teacher implementation of their curricula in their daily instruction.

2.11 Summary

This literature review has showcased the relationships amongst NGSS, teacher PD, and teacher change. In doing so, the literature has also revealed information that is often cited within scholarly papers but is questionable. These areas include the design features that have been traditionally referenced as making teacher PD effective, and the long-held notion within the literature that teachers do not tend to make changes in their practices. Additionally, this paper has highlighted identified gaps in the literature. However, in conjunction with a study by Channell and Cobern (2018), parent understanding and support of NGSS has been identified as a
gap in the literature that is undocumented in scholarly journals. The questionable components of the literature, as well as the previously unidentified gap in the literature, have motivated general research areas for future work.

2.11.1 Questioning Established Design Features of Effective PD

Traditionally, PD developers have relied upon the set of program design features found in the literature such as work by Garet, Porter, Desimone, Birman, and Yoon (2001), Yoon, Duncan, Lee, Scarloss, and Shapley (2007), Blank, De las Alas, and Smith (2008), and Desimone (2009). As detailed earlier in this review, these features include having a strong focus on content and curriculum; providing opportunities for rich and active learning; encourage collective participation with other teachers; having coherence with teachers’ daily practices and previous PD experiences; having alignment with national, state, and local standards and policies; employing sustained, ongoing learning, while giving teachers sufficient time to learn and develop; and being informed by teacher learning theory. References to these works are frequently found in many PD programs as an assurance that their programs met these criteria. However, a recent review of PD programs by Kennedy (2016) suggests that simply including these program design features may not lead to program success.

A focus on content knowledge has traditionally been a feature of effective PD. Kennedy (2016) notes that PD programs that focus exclusively on content knowledge tended to have less effect on student learning, while more successful programs operated under a broader goal, such as helping teachers learn to expose student thinking. Collective participation through PLCs was also investigated by Kennedy (2016), and found an abundance of variability in how these groups operated and performed. For example, Gersten, Dimino, Jayanthi, Kim, and Santoro's (2010)
Research Study Group model for PLCs, where teachers were given research questions to think about, then held discussion mediated by a designated leader, was found to be effective. However, another PLC that functioned through video-based lesson analysis had a negative impact on student learning. Because of this variability in effectiveness, Kennedy (2016) suggests moving past the mere incorporation of PLCs in schools and researching deeper into the content the groups discuss and the nature of the work they are engaged in. Collective participation through coaching was also a program design feature that found to have variable levels of value. Coaches that tended to observe and evaluate teachers were found to be less effective than coaches that collaborated with teachers on lesson planning and teaching practice.

Kennedy (2016) notes that the sustained intensity of a program and number of hours teachers spend in PD, as well as how those hours are distributed over time, has long been held as a key aspect to effective PD. For example, Greenleaf et al.’s (2011) PD program was based around lasting for a long span of time, whereas other programs have been built around a bulk of contact hours (Fetters et al., 2002). However, Kennedy's (2016) review revealed that programs with the greatest intensity were not necessarily more likely to be effective when compared to programs with less intensity. A successful PD program created by Roth et al. (2011) for elementary science teachers was purposefully to be short in duration, lasting only one year in length, sought to challenge the assumption that a single year is not enough time to impact teacher practice and student learning. Kennedy (2016) found that PD that provided teachers with strategies and insights, rather than with prescriptive messages, was more important than its intensity.

The findings of Kennedy's (2016) review challenges the notion that if a PD program contains the set of critical program design features that it will be automatically be effective. The
findings of the study steer research towards investigating the underlying organization, content, and practices found within PD programs that teachers experience. It also begs the question as to whether we should question some of the critical PD program design features as essential, especially intensity and number of contact hours. Additionally, the variability of designs found amongst the reviewed PD programs support Desimone and Garet's (2015) call for isolation of specific features of PD to study their influence.

2.11.2 Challenging the Notion that Teachers do not Change their Practices

Vázquez-Bernal, Mellado, Jiménez-Pérez, and Leñero (2011) note that while curricular changes in education are natural and necessary over time, the literature says that teachers do not usually make drastic changes in their beliefs and practices. Richardson (1998) acknowledges that the literature suggests teachers resist change because they want to cling to their old ways and that change makes people feel uncomfortable. However, Richardson (1998) challenges this concept, noting that throughout a career of being a teacher, teacher educator, supervisor of student teaching, and a researcher observing teachers in their classrooms, changes in teachers’ practices were observed regularly. Richardson (1998) proposes that teacher change is dependent on who is directing the change, and whether those changes are involuntary or voluntary on the part of the teacher. Richardson (1998) quotes Morimoto (1973) as stating, "when change is advocated or demanded by another person, we feel threatened, defensive, and perhaps rushed. We are then without the freedom and the time to understand and to affirm the new learning as something desirable, and as something of our own choosing. Pressure to change, without an opportunity for exploration and choice, seldom results in experiences of joy and excitement in learning." This infers that mandated PD with an intent to force changes in practice may not be effective in doing
so. However, Richardson (1998) goes on to state that while teachers try new ideas and make changes frequently, they may have unwarranted assumptions about what works and what does not, so support in the form of PD is still necessary. Richardson (1998) suggests that for PD to be effective in inviting teacher change, it needs to be empowering and group-oriented, involving all teachers developing and agreeing on longitudinal goals and concerns for students.

Contributing to the notion that teachers do not change their practices is a glaring lack of longitudinal studies on the long-term outcomes of teacher PD (Lawless and Pellegrino, 2007; Sandholtz and Ringstaff, 2016). Most studies on teacher PD model, such as those by Lotter et al. (2016), Tuttle et al. (2016), Shernoff et al. (2017) collect data on teachers for only a short period of time following PD experiences, though all of these studies call for future longitudinal studies. Stein and Wang (1988) demonstrated that when looking at long-term data on teacher success in program implementation and teacher perceptions of self-efficacy following participation in summer PD, patterns emerge throughout different parts of the school year. For example, the most significant improvements in the degree of implementation was between the fall and winter, while perceptions of self-efficacy increased most between the winter and spring (Stein and Wang, 1988). This sequence of changes in teacher behavior, followed by changes in belief, could not be observed over a matter of a few weeks or months. Rather, observations by the researcher needed to be conducted throughout the entire school year. Studies that collect data on the effects of PD on teacher change for only a short period of time following PD experiences do not include these long-term effects. Thus, the data presented potentially represents an incomplete picture of the effects of PD on teacher change. It is highly possible that teachers do change their practices, contrary to work in the literature that say otherwise (Jeanpierre et al., 2005), but that these changes take time to occur and are not observed by studies of shorter duration.
A rare example of a longitudinal study on teacher PD and change is Vázquez-Bernal, Mellado, Jiménez-Pérez, and Leñero's (2011) nine-year case study on a science teacher named Marina in Spain. In this two-phase study, Marina participated in PD through a collaborative research group in phase one but not in phase two. In phase one, Marina struggled with her teaching content and did not display self-efficacy. The PD she received during phase one would lead to a better ability to reflect on her practices, both individually and with her research group. This would develop into better teaching performance and self-efficacy in phase two, even when the research group was removed from her resources. It is worth noting that a contributing factor to Marina’s increase in teaching performance and self-efficacy could stem from the fact that she was not an expert in the content she was teaching in phase one but had a strong background in the content she was teaching in phase two. The content change introduces an outside variable that potentially affects the authors’ results; however, this change may have been out of their control. The content change can be downplayed due to the fact that science teachers can teach various classes and subjects throughout their years in the education profession. The important detail to glean from Vázquez-Bernal, Mellado, Jiménez-Pérez, and Leñero's (2011) study is that if observed over time, teachers will change their practices and beliefs.

2.11.3 Parent Understanding and Support of NGSS as a Barrier to Teacher Change

Currently, scholarly journals on parent understanding and support of NGSS are nonexistent, with the only literature existing on the subjects being in the form of educational web articles or blogs. Loewus (2014) presented a report shortly after the NGSS were released, citing that at the time, teachers and professors were generally in favor of the standards, but parents and politicians tended to know much less about them. Manley (2015) made an attempt to remedy the
lack of parent-targeted information regarding the NGSS, building a guide for what parents need to know regarding NGSS and three-dimensional learning. His guide included contrasts to how the NGSS presents topics differently than the scientific method, which most parents of today were exposed to when they went through school, as well as the concept of continuity from kindergarten to 12th grade.

Most recently, Loewus (2017) reported on how politicians increased understanding of the NGSS has led to backlash against the standards because of their inclusion of humans’ contributions to global warming, but that parent interest and understanding of the NGSS is still young. However, Loewus (2017) notes that once standardized testing aligned to the NGSS begins in 2018, parent questioning of the new standards may increase. She points out the recent backlash over new Common Core State Standards (CCSS) for mathematics, which include methods of calculation that many adults never learned in their schooling. Loewus (2017) notes that this backlash may foreshadow what’s to come with parent reception to the NGSS, especially given that districts have had trouble communicating with families about how classroom practices are changing in some disciplines.

Despite the lack of studies regarding parents and NGSS, literature related to parents and CCSS is a logical place to learn and draw inferences from. Unfortunately, scholarly research is also lacking in this area. Burks, Beziat, Danley, Davis, and Lucas's (2015) study investigates teacher comfort level and preparedness in teaching CCSS but does not acknowledge the role of parents in standards reform, minus noting that there are “conflicting views” that exist amongst parents and teachers. The lack of scholarly literature on parents and CCSS is possibly because of a generally undefined role for parents during times of educational reform. Remillard and Jackson (2006) point out that parents are generally left out of efforts to increase understanding of new
standards, and that attention and funds are directed towards teachers and administrators.

However, Remillard and Jackson (2006) are quick to point out that while parents should be viewed as having a role in their children’s education, they should not be viewed as equal partners within the context of education. Regardless, parents have been vocal in the media with their displeasure over CCSS and have made waves in their own regard. One parent interviewed by Monk (2013) stated, “Wait a minute: I didn't know about this? What's happening in my school? Why wasn't I involved in this?” Backlash from parents feeling “left in the dark” concerning CCSS (Neuman and Roskos, 2013) has led to many parents removing their students from public schools and opting for homeschooling. In Sioux Falls, North Dakota, the number of homeschooled students doubled following the introduction of the new CCSS K-5 mathematics curriculum (Anderson, 2014). A 2014 poll showed that many parents who had pulled their children to homeschool were purchasing more “classically aligned” textbooks, despite the increasing number of CCSS-aligned texts (Bidwell, 2014). However, attempts to better educate parents through informational sessions have been successful in changing parents’ minds regarding CCSS (Loewus, 2015). Such resources and sessions in regard to NGSS are extremely limited at the time.

Loewus (2017) points out the available resources for parents on the NGSS website. These sorts of resources are virtually the only parent-centered documents currently available for access online. One of these, an NGSS Parent Q&A document (National Science Teachers Association, 2017), presents parents with a simplified comparison of the NGSS with previous standards and curricula, and also notes how the NGSS will change science classrooms for children. The document also takes time to share statistics regarding the importance, growth, and even average pay for STEM-related professions, and what parents can do to aid in preparing their child for a
STEM-filled world. The NGSS website also contains a set of grade-band-sorted documents for what and how students will learn using the NGSS, with comparisons to traditional style classrooms and suggestions for parent involvement (Achieve, 2017). Given the lack of scholarly literature on parent understanding and support of NGSS, the limited number of available NGSS resources for parents, and what we should learn from parent understanding and reception to CCSS, research should be towards parents’ roles in the implementation of the NGSS.
CHAPTER 3
OVERALL PURPOSE OF THE STUDY

The gaps and questionable areas identified through the literature review, along with the results of a recent study by Channell and Cobern (2018) on teacher experiences following NGSS PD, have directed the overall purpose of this study. Three separate but connected studies were performed due to having two populations from which to gather data, teachers and parents, and the need to investigate teachers’ curricular materials following PD. The first and second study both utilize survey and interview tools but with separate populations. Since the first and second study are so closely intertwined, their purposes are detailed together below. The third study uses a rubric to obtain teacher and researcher evaluations of NGSS curriculum created following PD. While this third study is related to the first and second studies, it mainly functions as its own entity. Thus, the purpose of the third study is detailed independently below.

3.1 Teacher Experiences with Parents Following NGSS PD and Parent Understanding of NGSS

Channell and Cobern (2018) found that barriers to teacher change commonly documented in the literature, such as time, resources, and administrative support, have been issues for teachers attempting to align their classrooms with NGSS following PD. However, the study also produced an undocumented barrier to teachers changing their practices: parent understanding and support of NGSS. Teachers reported parent pushback, with parents criticizing the instructional styles of some participating teachers and claiming that it is not how their children learn. It was
forewarned by the National Academy of Sciences (2015) that teachers may experience resistance from students when aligning to NGSS, as students will not have had experience with NGSS-aligned teaching methods. However, the literature does not document parents as a potential impediment in NGSS reform. Parents are an important, but often overlooked stakeholder in education (Remillard and Jackson, 2006), and can play an important role in either supporting or hindering the daily work of teachers. The first two manuscripts in this study serve to give insight into how parents have influenced teacher change when aligning to NGSS, as well as the degree by which parents comprehend and perceive the changes that NGSS brings to their child’s learning environment. The first manuscript presents teacher experiences with parents during NGSS reform, while the second manuscript details parent understanding and support of NGSS.

3.2 NGSS Lesson Development and Implementation Following PD

Teacher PD is generally aligned with a set of program design features that are referenced throughout the literature as making PD more effective (Garet et al., 2001). However, Kennedy (2016) notes that inclusion of these design features does not ensure PD’s effectiveness to incline teachers to make changes. According to Richardson (1998), teachers are generally willing to make regular changes to their practices and curricula, but these sorts of voluntary changes can be based on the teacher’s personal beliefs and workplace situation (Fore et al., 2015). This means a teacher’s predisposition towards change may have a greater impact on change than the quality of the PD, as demonstrated in Johnson’s (2009) study. It has been documented that when NGSS PD does incline science teachers to make changes, the curricula they build can vary in quality in regard to its alignment to NGSS, despite teachers self-efficacy in building new lessons. (Shernoff et al., 2017). Connecting these pieces of the literature signaled the need for research into the
evaluation of both teacher perceptions of their newly built NGSS curricula following PD experiences, as well as an evaluation of their alignment with NGSS. The purpose of the second manuscript is to give insight into whether NGSS PD is inclining teachers to make changes in their curricula, and if so, contrast teacher perceptions of the quality of their work versus those of the researcher. The quality of these lessons may be associated with student learning and affect parent feedback received by teachers.
CHAPTER 4

TEACHERS’ PERSPECTIVE ON THE EXTENT TO WHICH PARENTS INFLUENCE
NGSS IMPLEMENTATION

Adam C. Channell, William W. Cobern, David Rudge, and Amy Bentz

Manuscript in preparation for submission to the *Journal of Research in Science Teaching*

4.1 Abstract

This study examined K-12 science teacher perceptions of parent understanding of the Next Generation Science Standards (NGSS), as well as accounts of interactions with parents during standards reform, following teachers’ professional development (PD) participation.

Fourteen teachers completed an online surveys and phone interviews. Themes, based on coded data, were constructed to represent relationships between teachers and parents during NGSS classroom implementation post PD. We found that teachers feel that parents are generally unaware of NGSS and not well-informed about the changes the new standards bring to their child’s science classrooms. Despite parents’ lack of NGSS understanding, teachers reported parents giving generally positive feedback about teachers’ science instruction. However, parents expressed concern about their child’s ability to transition between grade levels and subjects, the lack of an aligned textbook and homework assignments, and confusion with how to help their children at home in preparation for assessments. The results of this study suggest that it is important for school districts to adequately inform parents about the new NGSS curriculum and its implementation.
4.2 Introduction

The 2013 release of the Next Generation Science Standards (NGSS) prompted need for teacher professional development (PD) and subsequent changes in teacher practices and materials. The literature documents that following PD, teachers often encounter barriers and challenges during transitional implementation periods (Banilower et al., 2013; Johnson, 2006). Moreover, a recent study by Channell and Cobern (2018) revealed parents may be a previously undocumented barrier faced by teachers during NGSS implementation after PD. Parents are an important, but often overlooked, stakeholder in the education of children (Remillard and Jackson, 2006), and can heavily influence the actions of teachers. Participating teachers in the Channell and Cobern (2018) study reported pushback from parents who claimed that their students were not learning from NGSS-aligned teaching methods. The pushback was sufficient enough for some teachers to consider reverting back to their safer, previous instructional methods. Because of the Channell and Cobern (2018) findings regarding parents, the current study specifically investigated the role parents play in implementation of NGSS with the intention of informing district administrators, teachers, and PD practitioners how to better inform parents about NGSS, and how to increase parent understanding and support of the new standards.

4.3 Background

4.3.1 NGSS and Teacher PD

NGSS were released as a replacement for the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy and National Science Education Standards (Cooper, 2013). Based on the Framework for K-12 Science Education (National Research Council, 2012), NGSS is comprised of three dimensions: scientific and engineering practices,
crosscutting concepts, and disciplinary core ideas in science and engineering (McComas and Nouri, 2016). Teaching using the three dimensions is meant to give students a more authentic science experience within the classroom (Reiser, 2013), but implementation of all three dimensions within lessons is a challenge for science teachers. Teachers attend PD to learn how to implement NGSS, but how teachers have responded to PD efforts is not well documented (Shernoff, Sinha, Bressler, and Schultz, 2017). Johnson's (2006) study, and a national survey by Banilower et al. (2013), revealed many common factors that science teachers perceive as barriers to improving instruction. Some of these barriers include planning time, available time for PD, testing policies, and student academic ability. However, it is unclear what new barriers may have arisen for teachers since the release of NGSS.

4.3.2 Prior Work Leading to the Current Study

In an effort to update the literature regarding teacher-perceived barriers to NGSS implementation, Channell and Cobern (2018) questioned science teachers about their experiences aligning lessons to NGSS following mandatory PD. A portion of the results of the study were consistent with what the literature has documented as challenges faced by teachers during standards reform. Some of these challenges included a lack of time, resources, and administrative support. However, a lack of parent support presented itself as a theme that the literature does not document. Teachers in the Channell and Cobern (2018) study reported that parents complained that their students were not learning from the new, NGSS-style lessons. While scholarly journals do not currently contain information regarding parent understanding and support of NGSS, there are a limited number of relevant web articles. Loewus (2014) noted parents and politicians had a limited understanding of NGSS, and Manley (2015) provides a
guide to how NGSS is different from many of today’s parents science education experiences.

More recently, Loewus (2017) notes that NGSS has garnered more attention by politicians because of its connection to teaching about human contributions to climate change, but that parent awareness of NGSS is still relatively low. Loewus (2017) points out that this could change after 2018 with standardized testing being aligned with NGSS. She also warns that the well-documented parental backlash over the Common Core State Standards (CCSS) could be mimicked with NGSS. A better understanding of parent awareness and support for NGSS and its new methods of teaching science, thus, could better direct future efforts to inform parents about the new standards and prevent CCSS-level pushback.

4.3.3 Theoretical Approach and Purpose Statement

Fore, Feldhaus, Sorge, Agarwal, and Varahramyan's (2015) Model of Subjectivation serves as the theoretical framework for this study. This model asserts that teachers do not enter PD experiences as a blank canvas, but rather, teachers’ experience PD while viewing what is learned through a subjective lens. This lens allows teachers to decide what components of their PD experiences will be useful within their classroom. Teachers will consider the realities of their profession while doing this in an effort to get by using available resources and time, as well as considering their students’ individual situations. For this study, the reality being investigated is the relationship between teachers and parents. Parents are a potential source of positive support in the form of communication and reinforcement to continue students’ academic endeavors at home, but parents can also become barriers for teachers if parents lodge complaints. Teachers in the Channell and Cobern (2018) study reported changing their teaching methods and classroom organization in an effort to avoid additional time spent handling parent confrontation. Given that
teachers filter what’s learned in PD through a subjective lens when deciding what will translate into classroom changes, and that Channell and Cobern (2018) found parents as factor that influences teachers’ decisions to change, this study seeks to better understand the relationship between teachers and parents during NGSS alignment. In particular, this study is meant to investigate interactions teachers have had with parents in regard to NGSS, as well as gauge how parents have affected classroom practices and organization during NGSS alignment. This information could allow teachers, administrators, and counselors to understand how to better inform parents about NGSS, and also inform PD practitioners as to how to improve PD experiences for teachers to include proactive methods of getting parents to buy into differences in classroom practices.

4.4 Research Questions

1. What are the characteristics of parent/teacher communication in regard to NGSS implementation?
2. From these communications, what concerns do teachers have about parent understanding and acceptance of NGSS?
3. To what extent do teachers feel that parents have influenced implementation of NGSS?

4.5 Methods

4.5.1 Instrumentation

The survey and interview questions were formed to gather teachers’ comments on their experiences with parents during NGSS implementation following a PD experience (see Appendix A). The interview tool is based on a set of statements that appeared to be relevant
based on the results of the Channell and Cobern (2018) study, and the survey tool is comprised of combination of Likert-scale items and constructed response questions that were developed to compliment the interview questions. For validation, the instruments were piloted with a practicing elementary teacher, middle school teacher, and high school teacher prior to formal use. The researchers modified the survey and interview questions based on feedback from these teachers about the clarity and quality of the questions. The data for this study includes survey results, audio recordings, and coded transcripts of interviews. Participant names were masked within the data files and data collection matrix to ensure confidentiality.

### 4.5.2 Participants and Data Collection

Teachers who attended NGSS PD within the last two calendar years (2017 or 2018) were recruited from four Midwestern school districts. All recruited teachers experienced the same PD program, called NGSX, as a mandatory requirement by their districts of employment. The PD sessions occur outside of the buildings in which the teachers work and total 36 hours spread over the course of two to three weeks. NGSX is described by the PD practitioner who administered the training as follows:

“NGSX is an immersive experience for teachers that helps them see how utilizing the science and engineering practices benefit student learning in the classroom. Teachers put themselves in the role of the student, then reflect on their experience and the facilitation techniques used throughout the training” (B. Tomlinson, personal communication, May 22, 2019).

When teachers are placed into the role of students during NGSX PD, they perform NGSS-aligned activities that include modeling, explanation, and argumentation. Teachers also view
classroom video cases that demonstrate NGSS-aligned activities taking place. The content of the NGSX sessions revolve around the behavior of matter and air pressure phenomena.

Sixty-five teachers were emailed an invitation to participate in a Qualtrics survey and a phone interview, to which fourteen teachers agreed to participate. Fourteen participants were adequate to reach the saturation point as described by Cobern (2018) where unique opinions discontinued to surface. All other non-participants were contacted to explain their reasoning as to why they would not participate, and those who responded cited that they lacked time in their schedules. The invitation email explained the purpose of the study, the process of financial compensation, and included a statement of confidentiality.

**Table 1** Descriptive statistics for the study population (N = 14)

<table>
<thead>
<tr>
<th>Demographic</th>
<th>% of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50.0%</td>
</tr>
<tr>
<td>Female</td>
<td>50.0%</td>
</tr>
<tr>
<td>Grade Bands Taught</td>
<td></td>
</tr>
<tr>
<td>K-5</td>
<td>21.4%</td>
</tr>
<tr>
<td>6-8</td>
<td>21.4%</td>
</tr>
<tr>
<td>9-12</td>
<td>57.1%</td>
</tr>
<tr>
<td>Years Taught Full-Time</td>
<td></td>
</tr>
<tr>
<td>0-4 years</td>
<td>21.4%</td>
</tr>
<tr>
<td>5-10 years</td>
<td>7.1%</td>
</tr>
<tr>
<td>11-15 years</td>
<td>35.7%</td>
</tr>
<tr>
<td>16+ years</td>
<td>35.7%</td>
</tr>
<tr>
<td>Type of District Employed Within</td>
<td></td>
</tr>
<tr>
<td>Suburban</td>
<td>14.3%</td>
</tr>
<tr>
<td>Rural</td>
<td>71.4%</td>
</tr>
<tr>
<td>Math and Science Specific</td>
<td>14.3%</td>
</tr>
</tbody>
</table>
### Table 2 Descriptive statistics for individual teachers

<table>
<thead>
<tr>
<th>Teacher Number</th>
<th>Gender</th>
<th>Grade Bands Taught</th>
<th>Years Taught Full-Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>K-5</td>
<td>16+ years</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>9-12</td>
<td>16+ years</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>9-12</td>
<td>5-10 years</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>6-8</td>
<td>16+ years</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>9-12</td>
<td>5-10 years</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>9-12</td>
<td>11-15 years</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>9-12</td>
<td>16+ years</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>9-12</td>
<td>0-4 years</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>9-12</td>
<td>11-15 years</td>
</tr>
<tr>
<td>10</td>
<td>Male</td>
<td>K-5</td>
<td>11-15 years</td>
</tr>
<tr>
<td>11</td>
<td>Female</td>
<td>K-5</td>
<td>11-15 years</td>
</tr>
<tr>
<td>12</td>
<td>Female</td>
<td>6-8</td>
<td>11-15 years</td>
</tr>
<tr>
<td>13</td>
<td>Female</td>
<td>6-8</td>
<td>0-4 years</td>
</tr>
<tr>
<td>14</td>
<td>Male</td>
<td>9-12</td>
<td>16+ years</td>
</tr>
</tbody>
</table>

### 4.5.3 Data Analysis and Trustworthiness

Based upon previous pilot work related to the research questions of this study, an initial coding structure was created for analysis of the responses to the open-ended questions of the survey and to the interview. As the codes were applied during the data analysis, the need for additional codes emerged (see Appendix B). The resulting coding structure was applied to the teacher responses to highlight significant findings regarding interactions and challenges they faced with regard to parents during NGSS implementation. Throughout this process, a second university researcher reviewed the codes and their application to the survey and interview data as a measure of rater reliability. The Likert-scale items from the survey were not used in the results section of this study because of the small sample size of participants. However, teacher responses to these items were used as a measure of the reliability (consistency) of their responses.
4.6 Results

Three themes were derived from the data. These themes include feedback on teacher perceptions of parent awareness of NGSS, teacher accounts of parent feedback and concerns, and teacher suggestions for improving parent understanding of NGSS.

4.6.1 Teacher Perceptions of Parent Awareness of NGSS

Data suggested that teachers feel parents are unaware of the existence of NGSS, with around three quarters of teachers reporting this. Teacher 2 felt that his parent base knew NGSS existed, but knew little past that: “I wouldn’t say that they’re well-informed. I’d say they’ve heard of it, but they just kind of know that it [NGSS] exists. They don’t know how it [NGSS] functions.” This theme of parents not being well-informed about NGSS was shared by all of the teachers in this study. While many teachers did not feel that parents know much about NGSS, teachers expressed that parents understand that science education is different than from when they went through school. Teacher 8 shared the perspective that parents may not be against the idea of a new set of standards, they may simply be uninformed:

“There’s the pushback from students that’s there all the time, but when it comes to parents, I feel like they really just don’t really know what’s out there, or how it’s shifted so much from when they were in school.”

However, Teacher 8 worried that an uninformed parent could jump to conclusions about NGSS by associating the new standards with Common Core.

“I think parents hear NGSS, they sort of piggy back it onto the Common Core, and there’s a lot of fear in that. So, I think that if this kind of became more mainstream, the name alone, having a bit of that fear reaction could be a problem.”
If parents are uninformed about NGSS, a logical question is who within school districts should be sharing information with parents. Unfortunately, data suggests that this is not one single party, as school employees in general have done a poor job sharing information about NGSS. All but one participant commented that administrators and counselors have done a poor job informing parents about NGSS. “I have never seen or heard anyone who has specifically informed parents of NGSS”, claimed Teacher 1. Teachers, however, have not done much better. Only three of the participating teachers had informed their own students’ parents about the status, and those teachers who had informed their parents about NGSS only did so in brief mentions at parent/teacher conferences or open house. Moreover, all of the participants agreed that none of the parents were aware of NGSS resources for parents even if the parents were aware that NGSS was being implemented at their children’s schools. Teacher 5 noted, “I don’t think parents are aware of those resources at all.”

When teachers were asked to comment on the adequacy of the NGSS resources available for parents, most teachers did not know that resources for parents existed at all. As Teacher 9 put it, “Even I don’t know about those. It would be great if I knew what those were!” Several teachers related the situation back to their PD training about NGSS and felt that parent communication and getting parents to buy into new methods should’ve been addressed in their sessions. “I think that the PD that we get should encompass quite a bit more. Like include more resources. Or show more things out there. Because I didn’t even know that there was anything for parents for NGSS.”
4.6.2 Teacher Accounts of Parent Feedback and Concerns

Given that the teachers believed parents to be unaware or uninformed about NGSS, it’s not surprising that most of the teachers had received no feedback from parents regarding NGSS. “I don’t think there’s really been positive or negative feedback in either way, specifically about NGSS,” reported Teacher 5. Teachers who did receive feedback from parents reported that parents are relieved that science education is different than when they were students. As Teacher 12 explained, “The parents like to see that their child is ‘doing’ science, instead of just learning about it.” Despite parents being reported as generally satisfied with their children’s science instruction, there were areas of concern and confusion that teachers described about their students’ parents. Several teachers reported parents being concerned about their child transitioning between grade levels (i.e. 8th to 9th grade) and subject areas (i.e. biology to chemistry). While parents may not fully understand the role that NGSS plays in transitions between grades and subjects, teachers seemed to be aware of the relation. When students initially encounter a new grade level and subject area, they face not only new science content, but new NGSS-aligned practices. Teacher 9 explains:

“I think the challenges are most in the beginning of the year, when their grades are low, because they’re used to their high-flier students getting A’s, and then they jump into a whole NGSS-modeling biology curriculum and they have a C. Parents don’t understand that kids need to learn that way, because they aren’t used to it either, and then the grades start to come up and they do OK with it after that. Probably around Christmas. But the first couple months are rough.”

Teacher 9 went on to describe that while things tend to turn out alright for students in the end, the initial learning curve for students can lead to parent frustration. Teacher 9 suggested that if
schools were more proactive with educating parents about challenges students will face between grade levels and subjects, such as a potential dip in student scores early in a new class, that level of parent frustration might be lessened.

Another concern which parents have reported to teachers is being unsure as to how they can help their child learn science. With the introduction of NGSS, many science teachers and departments have moved away from textbooks that contain practice problems for students. However, this information does not seem to be relayed to parents. As Teacher 6 explained:

“I get two forms of feedback. It’s either, “hey, my kid loves what you’re doing”, because we teach with phenomenon. Or, “why is there not a textbook that my kid is getting that I can follow so I can help them with practice problems?” Those are my two different forms of feedback that I get…they just want to feel as though they can help their kid.”

Other districts have not abandoned textbooks but are delaying the purchase of NGSS-aligned textbooks in an effort not to waste funds before their science department can choose a text that they feel is adequately developed. In the meantime, students in these districts are being given old textbooks that are not aligned to NGSS. The use of an outdated text has caused issues with parents understanding how to help students, as they do not correlate well with the NGSS-aligned lessons performed in class.

“We know that students and parents want to have a textbook associated with our classes. They need to be able to see things and have some place where they can get some information or study for tests. Some of that information is in their textbook, but it is not exactly how I’m teaching it every day. So that’s where a lot of the parents don’t quite understand that, and they think they should be doing written skill sheets, fill in the blank, and that sort of thing. But those things aren’t happening.”
In addition to the lack of a textbook or an NGSS-aligned text, teachers have also received feedback from parents that they are unsure as to how to help their child study before exams without practice worksheets. Teacher 6 explains:

“I think with the parents, they want their kid, the night before a test, to have a whole drill and kill. Like, this is exactly what the test is going to be. And so, working with phenomenon, it’s hard to come up with like, 20 new phenomena for them to explain. Because all of our tests are about, explain this new scenario with knowledge that you already have. I’ll tell you, though, the majority of the parents love it after they’re done. They’re like, “oh yeah, my kid can think through these problems”. And they love the interaction, and they love what they’re doing. But going through the process, the parents feel helpless.”

Eventually, parents seem to appreciate the problem-solving skills that students gain through NGSS lessons. However, parents are uneasy with the inability to help their students along the way. While teachers spoke of some parental concerns about grade level and subject area transitions for their children and confusion as to how to help their children at home, strong parental pushback mostly had to do with parents thinking that their child was not learning enough. Teacher 8 noted, “For the most part, they don’t really have an opinion. They’re like, ‘OK, that’s what you’re doing, that’s how you’re teaching your class.’ And then moving on. As far as pushback from the parents, I don’t think it’s directly towards NGSS, because I don’t think they know it exists. They push back when their student is complaining that they aren’t learning that way.” Opinions from teachers were mixed as to whether NGSS has increased the occurrence of this sort of pushback or not. Teacher 10 believed that the use of NGSS-aligned activities directly contributed to
student and parent frustration: “Some of the projects and stuff that we do are way over the kids’ heads. So sometimes that frustrates the kids, and their parents want to know why they aren’t understanding things.”

4.6.3 Teacher Suggestions for Improving Parent Understanding of NGSS

Teachers offered their opinions as to how to better inform parents about NGSS in the future, such as posting resources on the school website or having handouts at school events where parents would be present. However, some teachers offered more innovative suggestions. One of these was to set up short, teacher-led presentations at school events such as parent/teacher conferences or open house. Teacher 4 explained how this would be more effective than handouts at such events:

“If you just have handouts, they’re just going to say, ‘whatever.’ But if you have this cool activity you could stop and try, and say, ‘this aligns with the new NGSS standards, and this is what we are pushing here.’ or making parent resources more visible online in the form of the school webpage and social media.”

Teacher 1’s district has already created an entire science evening for parents to meet their student’s science teachers and engage in some examples of in-class activities, but at this point the evening is not related to NGSS. However, this seems to be in the works: “I think you could take that one step further…and have an NGSS room where somebody is kind of going, “this is what’s happening in science.”

Teacher 11 suggested making better use of social media on a weekly or monthly basis to give parents a visual of what is going on within their classroom:
“I do a lot of parent communication every week via email or Facebook, so that would also be a great way to show parents what we’re doing. We do a lot of interactive stuff, so that would be a good way to show them.”

All of these suggestions are largely teacher-led, but some districts have been proactive in how they have presented, or are planning to present, a new NGSS-align curriculum to their parent body. According to teachers within these districts, the idea is to be transparent with parents about NGSS in an effort to avoid pushback. Teacher 12’s district already formally presented their new curriculum to parents, explaining that: “It looks very different, what the kids are doing…from someone on the outside looking in, one of the things that could be disturbing is that it looks like you’re letting the kids struggle.”

Some districts simply are not ready to present a full curriculum at this point in time, and are waiting for teachers to complete the NGSS alignment process before making an announcement to the community. Teacher 5’s district is close to being ready to present their new curriculum to parents, and was able to offer a unique perspective as he was one of six teacher representatives for the district’s science learning collaborative in charge of aligning to NGSS:

“So right now, we’ve gotten all the teachers to buy-in, we’re unpacking our performance expectations, we’re figuring out what’s going to look best for our district and where to put those performance expectations. After we get that set, our next step is going to be how we get it board approved, but number two, how we roll this out to our community. We have counselors involved and our admin team involved in the sequencing process to kind of help prevent some of those issue later where we might get pushback.”
4.7 Discussion

Most of the teachers in this study were of the opinion that parents are unaware of the existence of NGSS, and all of the teachers agreed that parents are not well-informed about the standards even if they were aware of them. The blame can be spread broadly because while the teachers imply that administrators and counselors were not doing an adequate job informing parents about NGSS, neither did they think that teachers were doing any better. Moreover, many teachers were not even aware that NGSS parent resources exist. Teacher 8 expressed concern that without information being shared with parents, NGSS could be wrongly associated with the negative perceptions that parents may have about the Common Core standards. However, according to some participants in this study, there are districts that are carefully planning the rollout of their new NGSS-aligned science curriculum, including presentations for parents.

On the other hand, given the perception that parents are generally uninformed about NGSS, teachers reported little feedback directly relating to the new standards and little pushback or challenges from parents that might impede their implementation of NGSS. Most teachers said that parents seemed satisfied with their children’s science instruction and its differences from the way they learned science in school. However, these differences have led to some issues of confusion and concerns for parents. Transitional periods, such as switching grade levels or science subjects, will always be challenging for students and frustrating for parents of students who struggle, and NGSS has added to this issue. As the National Academy of Sciences (2015) point out, it may be years before teachers see students moving up through school having already had many NGSS-aligned classes. The increased amount of writing and explanation that students face with NGSS-style lessons, coupled with new science content, has led to the early months of new grade levels and subjects being increasingly difficult. Additionally, the problem-solving and
phenomena-based lessons and assessments that students encounter, coupled with the lack of a textbook or NGSS-aligned textbook, has made it challenging for parents to be proactive in helping their children with their schoolwork or preparation for tests and quizzes.

4.8 Conclusion

Different school districts are in various stages of introducing their parent base to NGSS. Some districts have made no efforts, be it because they are still in the process of reshaping their curriculum or because doing so has not been made a priority. Other have already rolled out their new science curriculum to parents, and some are in the process of preparing to do so. These districts have carefully taken their time to ensure that their new curriculum was fully formed, district employees had bought-in, and the schoolboard approved. According to a recent story by Brody (2017), this slower, more deliberate approach to unveiling a new curriculum is exactly the reason why NGSS has not been receiving the same sort of backlash that the Common Core received when it was implemented in a hasty fashion. Districts that have not yet completed and/or presented their new science curriculums would be advised not to procrastinate in the process of building a formal presentation for their parents, but learning from Common Core, districts would be advised not to present until a well-thought-through plan is in place.

Teachers view what they learn during PD through a subjective lens and consider how factors within their individual realities affect their ability to make classroom changes (Fore et al., 2015). Channell and Cobern (2018) found that parents were a factor that, initially following NGSS PD, gave strong enough pushback for some teachers to initially revert back to their traditional methods. However, teachers in this study reported that over months of use of NGSS-aligned lessons in their class, students and parents eventually were at ease with the new style of
teaching. This was not before several months of struggle and confusion for students and parents. Taking a more proactive approach with parents to inform them what to expect in their child’s NGSS classroom may save all parties a lot of frustration. It is possible that districts that are not yet ready to unveil a full curriculum to parents could do so without a full-scale presentation. Rather, districts could introduce NGSS as a general concept that is gradually being adopted. Teachers could utilize some of the suggestions made by participants in this study, using open houses, parent/teacher conferences, or social media to increase transparency to parents regarding how classroom practices and organization may be different than in the past. Use of the parent resources guide (Achieve, 2017) and Q&A documents (National Science Teachers Association, 2017) available on the NGSS website could allow teachers an easy way to contrast these differences. Additionally, if teachers do not have an NGSS-aligned textbook or regularly assign homework to students, schools should provide parents with other resources to help them aid in their student’s science learning at home. By doing this, districts would buy themselves additional time to continue to align curriculum before making a formal rollout while keeping parents from being frustrated and confused about NGSS-style classroom practices and organization. To summarize, the data from the teachers in this study suggest that the following would be good practice:

• Districts should have a planned, deliberate method of presenting new, NGSS-aligned curricula to parents.
• Prior to presentation of new curricula, districts should share general information about NGSS to parents, such as the parent guide and Q&A documents available online.
• If textbooks and regularly assigned homework are not being used, teachers should provide parents with resources to help with science learning at home.
4.9 Limitations and Future Work

A limitation of this study includes the use of teachers in Midwestern districts, preventing the findings from being generalized to other geographic regions. However, teachers did come from a variety suburban, rural, and math and science specific districts. Additionally, PD sessions for teachers took place at different points in time (2017 versus 2018) for the participants. Teachers who had undergone PD more recently may not have had as long to attempt to align their practices with NGSS, and thus may have had fewer opportunities to interact with parents.

This study presents multiple opportunities for future research. Districts that have already rolled out their new, NGSS-aligned curriculum to parents could be interviewed about the steps taken in order to do so. This information could inform other districts about what went well, and what did not, in the process of presenting a new curriculum to the community. A study of this sort could also extend to parents within these districts, gauging understanding and support for NGSS following a district-led presentation of the new standards. Another avenue for future research could involve a smaller-scale introduction of NGSS in general to parents. Rather than unveiling an entire curriculum to parents, districts that are not ready for this step could make use of the suggestions from the participants of this study to inform parents about NGSS. The effectiveness of such efforts could be researched with both teachers and parents as subjects.
CHAPTER 5
PARENT ACCOUNTS OF UNDERSTANDING AND SUPPORT FOR NGSS

Adam C. Channell, William W. Cobern, David Rudge, and Amy Bentz

5.1 Abstract

The focus of this study was the parents of K-12 students. The study investigated parental awareness and understanding of the Next Generation Science Standards (NGSS), identifying areas of approval and concern with respect to their children’s science instruction. Fifteen parents participated in an online survey and phone interviews. Findings from the data suggest that parents are generally unaware of NGSS, and that districts have not made attempts to inform parents about standards reform. While the majority of parents claimed they were generally satisfied with the science instruction their children receive, parents had misconceptions about the current state of science education and what constitutes quality science education. Additionally, some parents expressed concerns about their students struggling with the NGSS-style methods employed by their science teachers and reported confusion about the lack of textbooks or homework associated with their child’s science classes. Despite being motivated to help their students continue to learn science outside the classroom, parents felt unsure as to how they could do so in the new NGSS environment. Thus, the results suggest that parents have been generally left out of the conversation regarding NGSS despite being an important stakeholder in education. Regardless of whether school districts are ready to present a fully overhauled NGSS curriculum to parents or not, results from this study suggest that districts should attempt to make immediate,
smaller-scale efforts to inform their parent bodies about NGSS, the changes these efforts bring to their children’s classrooms, and how parents can support science learning at home.

5.2 Introduction

Following Next Generation Science Standards (NGSS) professional development (PD) experiences, teachers have encountered many barriers and challenges that have previously been documented in the literature. Some of these barriers include time constraints, a lack of funds, and a lack of resources (Banilower et al., 2013; Johnson, 2006). A recent study by Channell and Cobern (2018) found that parent pushback may hinder teachers attempts to align their instructional practices with NGSS. Some participating teachers in the Channell and Cobern (2018) study cited parent complaints that the new methods of instruction were not cohesive with the way their child learns science; yet, parental influence has not been well-documented in academic journals as a barrier to teachers implementing new science standards. With standardized testing becoming aligned to NGSS in 2018, parent attention to NGSS will only increase (Loewus, 2017), and thus, research is needed to gauge parent understanding and support for NGSS. This study serves to inform district administrators, teachers, and PD practitioners about the current state of parent awareness in regard to NGSS, as well as to how to proactively inform parents about the new standards.

5.3 Background

Parents are an often overlooked stakeholder when it comes to educational policy and standards reform (Remillard and Jackson, 2006), and there is only a limited number of articles that can shed light on parent understanding and support of NGSS. Loewus (2014) found that shortly after the release of NGSS, parents and politicians had little understanding about the new
standards. Three years later, Loewus (2017) reported that while politicians had become increasingly aware of NGSS because of the inclusion of climate change content, parents were still largely uninformed. However, Silander et al. (2018) found that the majority of parents want to help their children with science at home, despite being unaware as to how to do so. It may be wise for school districts to proactively inform parents about NGSS in an effort to help parents understand how they can help their children learn science outside of the classroom. Additionally, informing parents about NGSS could avoid potential parent backlash, similar to what occurred with the implementation of the Common Core State Standards (CCSS) for mathematics in years past. Scholarly literature is also lacking in regard to CCSS, but media coverage of parent backlash has been extensive. Articles by Monk (2013) and (Neuman and Roskos, 2013) quoted parents as being concerned with not being involved or informed about CCSS. Anderson (2014) and Bidwell (2014) both reported that many parents pulled their students from traditional school to be home schooled following the CCSS release. While parents do not hold the same level of importance in standards reform as school staff members (Remillard and Jackson, 2006), parental involvement regarding the CCSS rollout demonstrated, at minimum, indicate the importance of informing parents of what to expect when curriculum undergoes significant changes. The Channell and Cobern (2018) study suggested that parents can influence decision-making for teachers while aligning to NGSS. Understanding parents’ perceptions, feedback, and concerns regarding their children’s science education would be valuable information for school staff moving towards informing parents about NGSS.
5.4 Research Questions

1. To what extent do parents understand NGSS and how implementation of those standards will influence their students’ classroom experiences?

2. How comfortable are parents with their children being taught with NGSS?

3. What areas of approval and concern do parents have in regard to NGSS?

5.5 Methods

5.5.1 Instrumentation

The survey and interview questions (see Appendix D) were built to gather parents’ comments on their understanding and support of NGSS. The survey tool used a combination of Likert-scale items and constructed response questions that were developed to compliment interview questions. For validation, these instruments were piloted with parents of an elementary student, a parent of a middle school student, and a parent of a high school student and modified appropriately prior to formal use within the study. The researchers modified the survey and interview questions based on feedback from these parents about the clarity and quality of the questions. The data for this study includes survey results, audio recordings, and coded transcripts of interviews. Participant names were masked within the data files and data collection matrix to ensure confidentiality.

5.5.2 Participants and Data Collection

Parents of K-12 students from four Midwestern school districts were recruited via email. They received an invitation to participate in a Qualtrics survey and a phone interview, coupled with an explanation of the purpose of the study, the process of financial compensation, and a
statement of confidentiality. Fifteen participants were adequate to reach the saturation point as described by Cobern (2018) where unique opinions discontinued to surface. For the parents to receive financial compensation, they were required to participate in both the survey and interview associated with this study.

**Table 3** Descriptive statistics for the study population, N = 15

<table>
<thead>
<tr>
<th>Demographic</th>
<th>% of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>26.7%</td>
</tr>
<tr>
<td>Female</td>
<td>73.3%</td>
</tr>
<tr>
<td>Level of Education</td>
<td></td>
</tr>
<tr>
<td>High school diploma or GED</td>
<td>6.7%</td>
</tr>
<tr>
<td>Some college</td>
<td>13.3%</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>40.0%</td>
</tr>
<tr>
<td>Master’s degree</td>
<td>40.0%</td>
</tr>
<tr>
<td>Oldest child’s grade band</td>
<td></td>
</tr>
<tr>
<td>K-5</td>
<td>25.0%</td>
</tr>
<tr>
<td>6-8</td>
<td>16.7%</td>
</tr>
<tr>
<td>9-12</td>
<td>58.3%</td>
</tr>
<tr>
<td>Children qualify for free and reduced lunch</td>
<td></td>
</tr>
<tr>
<td>Qualify</td>
<td>6.7%</td>
</tr>
<tr>
<td>Do not qualify</td>
<td>93.3%</td>
</tr>
</tbody>
</table>

### 5.5.3 Data Analysis and Trustworthiness

Based upon previous pilot work related to the research questions of this study, an initial coding structure was created for analysis of the responses to the open-ended questions of the survey and to the interview. As the codes were applied during the data analysis, the need for additional codes emerged (see Appendix E). The resulting coding structure was applied to the parent responses to highlight significant findings regarding parent understanding and support for NGSS. Throughout this process, a second university researcher reviewed the codes and their application to the survey and interview data as a measure of rater reliability. Although the Likert-scale items from the survey were not used in the results section of this study, parent
responses to these items were used as a measure of the reliability (consistency) of their responses.

5.6 Results

Three themes were derived from the data. These themes include parent awareness of NGSS, parent feedback, and parent concerns.

5.6.1 Parent Awareness of NGSS

Almost all parents report that they are unaware that NGSS exist and were only made aware of the standards by participation in this study, regardless of the grade band their children were in. Parent 1 explained: “No, I haven’t heard of NGSS at all, which is so interesting. So now it makes me more curious about this program.” Parent 14 has a daughter in high school, and another who recently graduated and has entered a science undergraduate program, who Parent 14 felt would have been in an excellent position to have been aware of NGSS. However, Parent 14 reported:

“Honestly, I know nothing. I even asked my daughter, who’s still in high school about [NGSS], and she said she didn’t know either. I have another daughter who’s pre-med, and she also had never heard of [NGSS]. Which was alarming to me.”

This occurrence of students who are interested in studying science after high school and their parents not being aware of NGSS was not limited to one instance. Parent 12 also shared that his daughter, who moved through biology and chemistry before taking AP biology, was unaware of NGSS: “I know nothing. And I’m embarrassed to say that. And I’m on PTA and everything, so I’m a little surprised that I don’t know anything.” Even parents of students who attend schools
that specifically focus on math and science, such as Parents 2 and 4, claimed that school staff had made no effort to communicate information about NGSS, or where to find resources to become more aware of the new standards. Parent 11, who works as a special education teacher in science classrooms, offered a unique perspective on the lack of communication about NGSS as both a parent and a teacher:

“I really don’t think the parents have been informed. I have kids in the district, so I get everything they send out to parents, but working here, I even get more stuff through my staff email. Things saying like, ‘hey, this is going on.’ I get a heads up on it, but I still feel like there’s just no effort to get the information out there about what’s really going on in science classrooms, how they’re being run, how they’re different. The parents aren’t getting it. There isn’t even like a district-wide email mentioning this stuff, it just doesn’t happen.”

5.6.2 Parent Feedback

Despite a lack of knowledge about NGSS, parents are generally pleased with the instruction their children receive. Parent 1 said:

“I think my daughter is more open to learning about science than she’s ever been. Maybe it’s the teacher, maybe it’s this NGSS program that he’s applying, I’m not sure. But more this year than ever before I’ve heard more from my kids that they are loving science.”

Many parents were simply happy with the differences between their perception of how science is taught now in comparison to their experiences with science education growing up. Parent 14 explained:
“Oh, well I think things have changed a lot, and for the better. When I was in school, I felt like it was much more text-based. Things are more hands-on now. So, students learn more by doing things, rather than just being told things.”

Many parents were able to identify features of NGSS-style learning within their children’s science education without knowledge of the existence of the standards. Parent 13 noted that her high schoolers were often engaged in building models, and Parent 11 commented that solving problems was emphasized in his daughter’s middle school science class. Parent 2 observed shorter units and fewer topics for her children, and Parent 10 was happy with the reduction of rote memorization and increase in project-based learning in science. Parent 2 said that her daughter has expressed that she often, “feels like she gets to be a scientist.” Many parents reported that these types of experiences have not only made their children appreciate science but have also steered them towards pursuing a science career. Parent 4 explained:

“Both of my children are going to be scientists. I think John’s most influential course was physics. He took that his freshman year, and he’s taking advanced physics his senior year. I think ever since he took that class, he’s just known from day one that he wants a PhD in physics.”

However, some of these parents were unsure if their children’s increased interest in science careers was related to NGSS, as Parent 14 points out:

“Like I said, my older daughter’s science teaching was influential enough to where she entered into pre-med. I can’t say that was attached to any sort of standards, but since they’ve been around since 2013 like you said, they must’ve had some kind of impact.”
5.6.3 Parent Concerns

While nearly all of the parents in this study had positive feedback concerning their children’s experiences learning science, there were some areas of concern. Some parents reported issues with the teaching methods their child’s science teacher has been using. Parent 2, whose daughter attends a math and science specific high school that is heavily aligned to NGSS, explained:

“I think adjusting to the way her classes are run at the Math and Science Center is always a struggle for her…like how things are running in the classroom. The content isn’t as much of a problem as the [NGSS] teaching style.”

Parent 6 expressed that NGSS was actually used by her daughter’s science teacher as reasoning for poor scores:

“I’ve never heard the standards be used as that term, but at my daughter’s parent/teacher conference, her teacher was explaining why her grade was so low, and the standards were used as a justification purpose. On her test, she was allowed to go back and make corrections, which was good. But where she was struggling, I’m assuming that had something to do with NGSS.”

Parent 11, who works as a special education teacher in science classrooms, was able to offer insight into what he felt the largest area of parent concern is about NGSS-style instruction. He explained:

“The battle we’re fighting right now with kids…is that they are saying, ‘just tell me what I have to do.’ And we’re saying, ‘No, I’m not going to tell you what you have to do, you gotta work through this, you gotta problem solve.’ And the kids really get frustrated. And so do the parents, because their kids are struggling.”
Outside of the classroom, many parents felt confused and uneasy about the lack of a textbook. As Parent 10 noted:

“They don’t have science books that are used, like textbooks, I guess that’s different than from what I had as a kid. I sort of expect there’s going to be a textbook. The way they explained it is that they do different projects or different worksheets, and then they are building a textbook of sorts. So, all these worksheets that they do on these topics are then put into the workbook that they’re building, or the journal.”

Additionally, parents expressed confusion as to why they were not seeing science homework.

“She has not brought any science homework home. She will study before tests, but I don’t really know why she doesn’t have any homework,” said Parent 6. Parent 10 expressed frustration because of the lack of homework:

“I have never seen either one of them bring home homework for science. Which is another pet peeve of mine. They’ll have math homework or reading homework, but I’ve never seen them with science homework. But they both have A’s in science, and they’ve both maintained A’s in science, so it’s not like they aren’t doing their work. They have no issue getting an A. Which I think is bad.”

Parent 7 realized a reason behind her son’s lack of homework:

“I see very little homework brought home at the high school level. Most of the work he’s doing, he’s doing in class. So, he’s doing in-class labs. So, really, what he’s bringing home might be something he needs to study, but not something that he’s bringing home where he has to do homework.”
5.7 Discussion

The results suggest that parents who participated in this study are generally unaware of NGSS. Despite a lack of knowledge of the new standards, the majority of parents had positive comments about their children’s science education. Many parents noted that their son or daughter’s experiences in science classes were so influential that they have entered into, or are considering, science careers. Several parents commented on their approval of science being taught differently than it was when they were students, and that students not sitting through lectures and readings each day was an improvement over the science education they remember as kids. However, parents expressed concerns about the lack of a textbook or homework. Based on the information gathered in this study, it is clear that the majority of parents are not up to date on current efforts to improve science education.

Parents in this study shared their concern for students struggling in class. As explained by Duschl and Bybee (2014), NGSS embraces the struggle of doing science to give students a more authentic science learning experience than what students had with inquiry-based learning. Essentially, parents are not aware that students may struggle in the process of explaining phenomena and solving problems in an NGSS-style curriculum, and that this is intentional. Parents may expect a more traditional instructional style, similar to what they experienced as students, where teachers deliver content and then score students on their ability to recite the answers. Parents need to be aware that a science teacher’s role has shifted from presenting ideas through lectures and textbook readings to helping students solve problems, form explanations and arguments, and form conclusions (Reiser, 2013). Additionally, parents need to be aware that teachers are still learning how to use NGSS in the classroom. Implementation of the three-dimensional learning approach brings many new challenges for teachers (Shernoff, Sinha,
Bressler, and Schultz, 2017), and the implementation phase of new strategies is documented to be when teachers struggle the most following PD opportunities (Han, Yalvac, Capraro, and Capraro, 2015). Parents should understand that many teachers need time to experiment with new materials and techniques in an effort to build a better learning environment for students (National Academy of Sciences, 2015).

Parents can be a valuable resource for science learning outside of the classroom. However, a recent study by Silander et al. (2018) suggested that while most parents are working hard to help their children learn outside of the classroom, many parents do not know how to help organize and support science learning surrounding their daily lives. Textbooks and homework represent safe places for parents to turn to in the past for guidance in aiding their children with learning science. However, many parents in this study shared that textbooks and homework are not used in their child’s science courses. This has led parents to be confused about why this is the case and has prevented them from feeling like they can support their student’s science learning, despite being motivated to do so. One explanation for the lack of textbooks that parents should be aware of is that many schools have either moved away from textbooks altogether, or the district is waiting on investing into NGSS-aligned texts until a book that best fits with the school’s new curriculum is identified (Channell and Cobern, 2018). Additionally, NGSS represents a move away from “drill and practice” style worksheets and rote memorization on exams, and have shifted science learning to using classroom time to solve problems and explain phenomena (Krajcik and Merritt, 2012). Since much of this work, such as group discussion and argumentation or model building and revision, is meant to be performed within a science classroom, it is not surprising that the amount of homework being assigned by teachers have decreased. Without an understanding of changes
like this that accompany NGSS, parents have been left as confused and unsure as to how they help their students at home.

5.8 Conclusion

The results of this study suggest that without the traditionally safe resources to help students learn science outside of the classroom, in the form of a textbook or regular homework, parents need communication from their districts and science teachers about NGSS and direction towards resources that will allow them to be of service. Silander et al.’s (2018) study supports this, as they found that parents want ideas, resources, and everyday materials to build their knowledge and confidence to help their children learn science. The NGSS Parent Guides available at the NGSS website (Achieve, 2017) include suggestions for parents to help support their children be successful in science such as speaking to a teacher or principal about how NGSS bring changes to the school, asking a teacher thoughtful questions based on the information provided in the Parent Guide, and learning how parents can help reinforce classroom instruction at home. However, parents in this study would only encounter these suggestions found on the NGSS website if parents were aware that the site, or NGSS in general, existed in the first place. That said, the responsibility to inform parents about NGSS must fall upon school district staff members. Silander et al. (2018) say that schools should be providing parents with ideas for activities that encourage conversations amongst family members that help children make connections between science experiences at home, school, and within the community. While enriching science learning experiences for students by increasing parent involvement at home would be enough of a justification for the benefits of informing parents about NGSS, teachers and school administrators would see benefits as well. For teachers, highly-involved
parents can act as a valuable resource for identifying phenomena and provide experience that teachers can leverage in their classes (Furtak and Penuel, 2018). However, parents can also become a hinderance for teachers by logging complaints and taking up valuable time that could be spent preparing or scoring lessons (Channell and Cobern, 2018). If parents were better informed about NGSS, parents could become more likely to be allies for teachers as opposed to barriers to NGSS implementation. Administrators should be aware that the literature provides evidence that students with involved parents tend to perform higher on standardized tests when compared to students with less involved parents (Remillard and Jackson, 2006). For parents to be involved, they need to be well-informed. Thus, if administrators are interested in higher scores on standardized testing for their district, it would be wise to be proactive with an increase in shared information and resources related to NGSS.

5.9 Limitations and Future Work

A limitation of this study includes the use of parents in Midwestern districts, preventing the findings from being generalized to other geographic regions. Additionally, only one parent in this study has children that qualify for free and reduced lunch, so the results of this study could not be applied to lower-income families. Finally, 80.0% of the participants in this study hold either a bachelors or graduate degree, meaning that parents with lower levels of education are not well-represented in this study.

The results of this study give direction for areas of future research. Parents were shown to not have an adequate understanding of NGSS, and districts had not made efforts to inform the majority of parents in this study about NGSS. Future research could involve creation of strategies to inform parent bases about NGSS prior to a full curriculum layout. Additionally,
construction of strategies for how parents can help continue their students’ learning at home could be helpful to better utilize parents as educational partners. A follow-up study with parents in both of these areas could then be performed.
CHAPTER 6
AN ANALYSIS OF TEACHER-CREATED NGSS-ALIGNED LESSONS

Adam C. Channell, William W. Cobern, David Rudge, and Amy Bentz

6.1 Abstract

In this qualitative case study, fourteen teachers who had built or heavily modified lessons to align to the Next Generation Science Standards (NGSS) evaluated their own lessons using the EQuIP rubric. Subsequently, the lessons were evaluated by two NGSS experts, the researcher and the PD practitioner who had led the NGSS professional development (PD) for these teachers. The three sets of EQuip evaluations were then summarized in terms of strengths and weaknesses vis-à-vis NGSS, and the teachers’ evaluations and the experts’ evaluations were then compared and contrasted. The data analysis indicated that for most of the teachers’ lessons, EQuIP evaluations compared well with the experts’ evaluations for the categories of Explaining Phenomena or Designing Solutions, Use of Three Dimensions: SEPs, Use of Three Dimensions: DCIs, and Integrating the Three Dimensions for Instruction and Assessment. However, teacher quality ratings were a mix of higher and lower as compared with the experts’ evaluations for the categories of Use of Three Dimensions: CCCs and Generation of Student Ideas. The experts generally gave lower quality ratings for Relevance and Authenticity and Building on Students’ Prior Knowledge. The findings suggest that following initial NGSS PD, there will be areas where teachers need continued attention in future PD sessions. Additionally, the variability of teacher and expert responses in several categories suggests that PD include efforts to improve teacher skills and self-efficacy using the EQuIP rubric.
6.2 Introduction

Professional development (PD) modules for the Next Generation Science Standards (NGSS) have been administered to teachers in an effort to inform them about the new standards and increase self-efficacy in building new lessons that are aligned to NGSS. However, the quality of alignment with NGSS following PD is not well documented. A study by Shernoff, Sinha, Bressler, and Schultz (2017) showed that while many teachers displayed increased self-efficacy in building new lessons, a closer examination of their lessons revealed many areas that did not fully align with NGSS. Shernoff et al. (2017) call for additional research into teacher-created lesson plans following NGSS PD. In this study, 14 teachers self-evaluated a lesson they created or heavily modified to align to NGSS using the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric. This was followed by an evaluation of the teacher lessons by the researcher and the PD practitioner who administered the NGSS PD to the teachers. The rubric evaluations were contrasted to reveal themes in lesson strengths, weaknesses, and potential discrepancies in level of NGSS alignment. The results demonstrate the current ability of teachers to create NGSS-aligned materials, as well as areas where teachers need continued support and additional PD opportunities.

6.3 Background

6.3.1 NGSS and Teacher Lessons

With the introduction of NGSS in 2013, teachers have faced the challenge of building new lessons, or modifying existing lessons, to align to the new standards. These lessons should be built with the intention of satisfying the three dimensions that comprise NGSS, which include
disciplinary core ideas (DCIs), cross-cutting concepts (CCCs), and science and engineering practices (SEPs). The DCIs are essentially the science content that students will learn. Comparing NGSS to previous sets of standards put forth by the National Research Council (1996), there is a substantial reduction in the raw number of topics that teachers must cover each year. This reduction in content is meant to allow teachers to spend additional building deeper and richer learning experiences for students (Cooper, 2013). CCCs are concepts such as cause and effect, energy and matter, or systems and models that link the different areas of science (National Research Council, 2012). Finally, SEPs are meant to build upon the inquiry lessons developed in past years (Huff, 2016) by giving students a more authentic experience of the process of doing science (Duschl and Bybee, 2014). In addition to the three dimensions of NGSS, teacher lessons need to be more of a full instructional plan instead of a series of lessons that students are taught day-to-day (National Research Council, 2012). Some teachers may display understanding of the three dimensions of NGSS, but Shernoff et al. (2017) point out that many teachers may feel unsure as to how to make shifts in their teaching practices. In an effort to aid teachers in this process, teachers have been given PD, but the quality of teacher built or modified lessons following NGSS PD sessions is not well researched (Shernoff et al., 2017).

6.3.2 Teacher Change Following PD

For standards reform to be a successful process, teachers must learn new skills while also altering or letting go of their previously held beliefs and practices (Darling-Hammond and McLaughlin, 1995). This is, obviously, a difficult process for some teachers. Even when teachers feel motivated and ready to implement new lessons or techniques, it is documented that they can easily fall back into old habits (Briscoe, 1991). Additionally, when some teachers tend to
incorporate new features into their preexisting system of teaching, rather than changing the system itself, the fundamental nature of their instruction remains the same (Stigler, 2000). Johnson's (2009) study showed that teachers’ personal beliefs play a large role in the impact PD makes on teachers changing their practices, as PD will be ineffective teachers who are predisposed to resist change.

Several potential barriers could affect teachers aligning their lessons to NGSS. Teacher self-efficacy in building NGSS lessons could be a potential issue. A study by Banilower et al. (2013) reported less than 10% of middle and high school teachers felt prepared to teach engineering concepts. Misunderstanding or underestimating the differences between NGSS and previous standards could be another barrier to building effective lessons. Bybee (2013) notes that some teachers may think that if a lesson addresses content found in the DCIs, then that lesson is aligned to NGSS. However, this lesson does not necessarily touch upon all three dimensions of NGSS. Additionally, some lessons may appear to be NGSS-aligned because they are “hands on”, but Huff (2016) notes that many of these types of lessons fall short because they do not have students build and test explanatory ideas. According to Kennedy (2016), teachers must be prepared to dramatically shift their teaching practices to become NGSS-aligned. Simple modifications of existing lessons may not be adequate, and some preexisting lessons may need to be thrown out entirely (National Academy of Sciences, 2015). Participants in a study by Channell and Cobern (2018) showed that the majority of teachers were open to changing their practices and lessons following NGSS PD, and this study is meant to evaluate those lessons since they have been implemented in the classroom following that PD.
6.3.3 Theoretical Approach and Purpose Statement

The theoretical framework utilized for this study is Fore, Feldhaus, Sorge, Agarwal, and Varahramyan's (2015) Model of Subjectivation. Within this model, teachers are assumed to enter PD opportunities carrying their own personal beliefs and knowledge, which act as a subjective lens that PD experiences are filtered through. By doing this, teachers are able to assess how new information could be used, or not, in their own classroom. Teachers in Channell and Cobern's (2018) on teacher evaluations of their NGSS PD experiences considered the realities of their individual professional situations when attempting to implement what they’d learned into their classrooms after PD. Factors such as time, budget, resources, and personal beliefs were considered by teachers. This study evaluates lessons created or modified by teachers following their NGSS PD experiences. The results of the study could be used to inform PD practitioners as to strengths and weaknesses teachers have in regard to crafting NGSS lessons. Additionally, gathering teacher opinions of their own lessons could reveal how well teachers are able to successfully use the EQuIP rubric as a tool to self-evaluate. If teachers are consistently evaluating themselves improperly, PD practitioners may want to incorporate training on use of the EQuIP rubric into future PD programs. Finally, an assessment of teacher lessons could add to the story of how well NGSS is being implemented into classrooms. While it is unreasonable to expect teachers to be experts in new content following PD (Abell, and Lee, 2008), misaligned lesson plans could indicate poor NGSS-style instruction in the classroom.
6.4 Methods

6.4.1 Instrumentation

Teacher-built NGSS lesson plans were analyzed using the EQuIP rubric by both the teacher, the researcher, and the PD practitioner who administered NGSS PD to the teachers. The EQuIP rubric utilizes six categories of lesson evaluation. The first three of these categories are NGSS shifts, including explaining phenomena or designing solutions, use of three dimensions, and integrating the three dimensions for instruction and assessment. The second set of categories include general features of quality design, including relevance and authenticity, generation of student ideas, and building on students’ prior knowledge. The method of data collection in this study is modeled after the steps taken in Shernoff et al.’s (2017) study, and was piloted with a group of 13 practicing teachers who are graduate students at Western Michigan University in the Summer 1 semester of 2018.

6.4.2 Participants and Data Collection

Teachers who attended NGSS PD within the last two calendar years (2017 or 2018) were recruited from four Midwestern school districts. All recruited teachers experienced the same PD program, called NGSX, as a mandatory requirement by their districts of employment. The PD sessions occur outside of the buildings in which the teachers work and total 36 hours spread over the course of two to three weeks. NGSX is described by the PD practitioner who administered the training as follows:

“NGSX is an immersive experience for teachers that helps them see how utilizing the science and engineering practices benefit student learning in the classroom. Teachers put
themselves in the role of the student, then reflect on their experience and the facilitation techniques used throughout the training” (B. Tomlinson, personal communication, May 22, 2019).

When teachers are placed into the role of students during NGSX PD, they perform NGSS-aligned activities that include modeling, explanation, and argumentation. Teachers also view classroom video cases that demonstrate NGSS-aligned activities taking place. The content of the NGSX sessions revolve around the behavior of matter and air pressure phenomena.

Sixty-five teachers were emailed an invitation to submit an NGSS-aligned lesson they have built and to self-evaluate that lesson using the Educators Evaluating the Quality of Instructional Products Rubric (EQuIP) rubric, to which 14 agreed to participate. All other non-participants were contacted to explain their reasoning as to why they would not participate, and those who responded cited a lack of time in their schedules. The invitation email explained the purpose of the study, the process of financial compensation, and included a statement of confidentiality.
### Table 4 Descriptive statistics for the study population (N = 14)

<table>
<thead>
<tr>
<th>Demographic</th>
<th>% of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50.0%</td>
</tr>
<tr>
<td>Female</td>
<td>50.0%</td>
</tr>
<tr>
<td>Grade Bands Taught</td>
<td></td>
</tr>
<tr>
<td>K-5</td>
<td>21.4%</td>
</tr>
<tr>
<td>6-8</td>
<td>21.4%</td>
</tr>
<tr>
<td>9-12</td>
<td>57.1%</td>
</tr>
<tr>
<td>Years Taught Full-Time</td>
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<tr>
<td>0-4 years</td>
<td>21.4%</td>
</tr>
<tr>
<td>5-10 years</td>
<td>7.1%</td>
</tr>
<tr>
<td>11-15 years</td>
<td>35.7%</td>
</tr>
<tr>
<td>16+ years</td>
<td>35.7%</td>
</tr>
<tr>
<td>Type of District Employed Within</td>
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</tr>
<tr>
<td>Suburban</td>
<td>14.3%</td>
</tr>
<tr>
<td>Rural</td>
<td>71.4%</td>
</tr>
<tr>
<td>Math and Science Specific</td>
<td>14.3%</td>
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</tbody>
</table>

### Table 5 Descriptive statistics for individual teachers

<table>
<thead>
<tr>
<th>Teacher Number</th>
<th>Gender</th>
<th>Grade Bands Taught</th>
<th>Years Taught Full-Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>K-5</td>
<td>16+ years</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>9-12</td>
<td>16+ years</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>9-12</td>
<td>5-10 years</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>6-8</td>
<td>16+ years</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>9-12</td>
<td>5-10 years</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>9-12</td>
<td>11-15 years</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>9-12</td>
<td>16+ years</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>9-12</td>
<td>0-4 years</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>9-12</td>
<td>11-15 years</td>
</tr>
<tr>
<td>10</td>
<td>Male</td>
<td>K-5</td>
<td>11-15 years</td>
</tr>
<tr>
<td>11</td>
<td>Female</td>
<td>K-5</td>
<td>11-15 years</td>
</tr>
<tr>
<td>12</td>
<td>Female</td>
<td>6-8</td>
<td>11-15 years</td>
</tr>
<tr>
<td>13</td>
<td>Female</td>
<td>6-8</td>
<td>0-4 years</td>
</tr>
<tr>
<td>14</td>
<td>Male</td>
<td>9-12</td>
<td>16+ years</td>
</tr>
</tbody>
</table>

### 6.4.3 Data Analysis and Trustworthiness

Participating teachers submitted their self-built, NGSS-aligned lesson plan and a completed EQuIP rubric to the researcher via email. Following this, the researcher and the PD practitioner
who administered the teachers’ NGSS PD also evaluated the lesson plans using the EQuIP rubric. This method of analysis is similar to methods used by Shernoff et al. (2017). The evaluations were compared and contrasted to build a set of themes regarding strengths and weaknesses in NGSS-alignment, as well as discrepancies in teacher perceptions of their own work and their actual alignment to NGSS.

6.5 Results

Results to this study have been broken into the six sections of the EQuIP rubric for presentation. Part B of the rubric, which examines use of the three dimensions of NGSS, has been broken down into three sub-categories. Teacher and researcher quality ratings are presented using side-by-side pie charts. The EQuIP rubric uses “inadequate”, “adequate”, or “extensive” as categories for quality ratings. The quality rating data is followed by commentary on specific lessons and trends amongst lessons for each section of the rubric.

6.5.1 Explaining Phenomena or Designing Solutions

The majority of lessons were rated Adequate for Explaining Phenomena or Designing Solutions by both teachers (92.9%) and the researchers (78.6%). Neither the teachers nor researchers rated their lessons as Extensive in this category of the EQuIP rubric. Eleven of fourteen teachers reported the same quality ratings for Explaining Phenomena or Designing Solutions as the researchers, one teacher rated themselves lower than the researchers, and two teachers rated themselves higher than the researchers.
There was evidence of multiple teacher lessons that revolve around phenomena. For example, Teacher 5’s lesson for 9-12 students about energy transfer during phase changes centered around citrus farmers spraying oranges with water before freezing temperatures occur. Teacher 6 used the Northern Lights as the center of a 9-12 grade lesson about the wave/particle duality of light. Other teachers showed evidence of problem solving as the focus on their lessons. Teacher 4 challenged groups of 6-8 students build a tower that would withstand an earthquake using a limited “budget” to spend on K’Nex pieces, while Teacher 2 had students working together to design a sustainable county for a large population.

Some lessons were rated by teachers as adequate but were rated as inadequate by the researchers. Teacher 7’s study on protist populations in pond water samples did not revolve around a phenomena or established problem. Students were asked to introduce one change into a sample of pond water, make a prediction, and record results over time to build a conclusion.
Teacher 14’s lesson on stoichiometry was rated by the teacher as adequate but also showed no evidence of use of phenomena or designing a solution to a problem. However, Teacher 11’s lesson for K-5 students was rated as inadequate by the teacher but actually did revolve around the phenomenon of why pumpkins change in appearance over time after they are carved.

### 6.5.2 Use of Three Dimensions: SEPs

While the category of Three Dimensions: SEPs had five teachers rating their lessons too high, this area of the EQuIP rubric still had the majority of lessons (71.4%) being rated as Adequate or Extensive by the researchers.

![Figure 7 Teacher Quality Ratings for Use of Three Dimensions: SEPs](image1)

![Figure 8 Researcher Quality Ratings for Use of Three Dimensions: SEPs](image2)

Many lessons only hit one SEP, but several lessons touched upon many. For example, Teacher 1’s lesson for K-5 students explored why babies tend to look like their parents, and showed evidence of asking questions and defining problems, planning and carrying out
investigations, developing and using models and obtaining, evaluating, and communicating information. Some lessons included multiple SEPs, but not all were executed properly. Teacher 10’s lesson on energy transfer for K-5 students includes student dialogue in the form of debate following an activity, but students do not construct their own investigation. Rather, the teacher lays the steps of the activity out for the students. Teacher 13’s lesson for 6-8 grade students on gene recombination has them analyzing and interpreting data, but students acquire that data from a model that is not constructed on their own through investigation.

6.5.3 Use of Three Dimensions: DCIs

Adequate or Extensive quality ratings for DCIs were in the majority for both teachers and the researchers. However, the researcher ratings included more extensive ratings than the teachers (21.4% versus 7.1%), as well as fewer inadequate ratings than the teachers (7.1% versus 14.2%). Only one lesson was marked as inadequate by the researchers, and this lesson was also marked as inadequate by the teacher.
All lessons but one scored highly by the researchers for this category of the EQuIP rubric. This should not come as a surprise, as Osborne (2014) points out that many teachers will have already mastered the science content within the DCIs prior to the release of NGSS. The single lesson marked as inadequate by both the teacher and the researcher, Teacher 7’s lesson for 9-12 students on pond water populations, did not contain an explicit DCI. However, as the teacher noted in the EQuIP rubric, this could easily be improved upon by building components of the life science DCIs for ecosystems, such as carrying capacity, into the lesson. An interesting finding was Teacher 4’s lesson for 6-8 students, where students constructed a tower from K’Nex on a limited “budget” to withstand an earthquake, was the only lesson addressed DCIs from Engineering Design. Teacher 2’s observed that during a lesson for 9-12 students that challenged them to build a county that could sustain a large population, students who had previously taken the school’s engineering course were able to use the skills they’d learned to improve their county designs. Teacher 2 proposed that in the future, they would better utilize the engineering class as a resource, potentially even having the lesson be a joint lesson between the two classes.

6.5.4 Use of Three Dimensions: CCCs

The majority of teachers and researchers rated the lessons as either Adequate or Extensive for Three Dimensions: CCCs (85.7% for teachers, 71.3% for researchers). However, no teachers rated their lessons as Extensive for this category of the EQuIP rubric. Further, four teachers scored themselves higher than the researchers, but another four teachers scored themselves lower than the researchers.
There was variability in the CCCs evident in the submitted lessons. The most common CCCs used in lessons were Energy and Matter (5 lessons) and Cause and Effect (3 lessons). However, Scale, Proportion, and Quantity, Scale and System Models, and Stability and Change were not evident in any lessons. Patterns were claimed to be present in three lessons, however, two lessons did not have adequate evidence of this CCC. Only one lesson failed to even attempt to address a CCC at all, to which the teacher acknowledged this shortcoming.

6.5.5 Integrating the Three Dimensions for Instruction and Assessment

The majority of teacher and researcher ratings for Integrating the Three Dimensions for Instruction and Assessment were Adequate or Extensive. The researchers ranked two teachers’ lessons higher than they ranked themselves, but four teachers rated their lessons higher than the researchers.
Some of the lessons that received Inadequate ratings by the researchers could be easily adjusted to receive an Adequate rating. Teacher 9’s lesson for 9-12 students contained a data component where students take measurements on their reaction time to stimulus, but there doesn’t seem to be evidence of this being followed up on much with the exception of one analysis question. The teacher mentions that this is followed up on in discussion, but this is not explicit within the lesson. Teacher 1’s K-5 lesson on traits moving from parent to offspring had discussion amongst students, but no visible document or model that puts a group conclusion together. In the teacher-completed EQuIP rubric, there is a mention of a journaling activity as an extension, but it is not specifically included. Finally, Teacher 7’s pond study lesson has extensive assessment of SEPs and CCCs, but lacks a DCI component.
6.5.6 Relevance and Authenticity

Seven lessons were rated as Inadequate by the researchers but as Adequate by teachers, and one lesson was rated as Inadequate by the researchers but as Extensive by the teacher. The majority of teachers rated their lessons as Adequate or Extensive (85.7%), but the researchers only ranked half of the lessons as Adequate and no lessons as Extensive.

Some of the submitted lessons showed direct evidence of community relevance. Teacher 2’s 9-12 lesson where students built a sustainable county for a large population incorporated planning for flooding using recent data from local areas that have had flooding issues in recent years. Teacher 6 was able to use the Northern Lights, which occur in proximity to his school, as the central phenomenon in a 9-12 lesson about how light behaves. Other lessons were well-constructed and aligned to NGSS but did not include phenomena or problem solving that could be related to students’ homes, neighborhoods, or communities. For example, Teacher 4 acknowledged that while his 6-8 grade level lesson was engaging, attempting to build a tower to

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*Figure 15 Teacher Quality Ratings for Relevance and Authenticity*

*Figure 16 Researcher Quality Ratings for Relevance and Authenticity*
withstand an earthquake had little relevance to students who live in an area where earthquakes do not generally occur. Teacher 5’s lesson was similar in the regard that his 9-12 lesson on energy transfer featured many well-aligned NGSS components, but citrus fruits are not farmed in the area where his students live. Teacher 5 reasoned that some students may have experience with agriculture, but wondered if a more relevant phenomena to the local area could be used. Teacher 7 rated her 9-12 grade level lesson on populations in pond water samples as Extensive for relevance and authenticity, with the justification for this being that the water came from a local water source. However, the researchers agreed that this does not necessarily mean that the lesson is relevant to the students’ lives or community, and the lesson was ranked as Inadequate.

6.5.7 Generation of Student Ideas

All teachers scored their lessons as Adequate or Extensive for Student Ideas, and the researchers rated the majority of lessons as Adequate or Extensive as well (78.6% total). However, three teachers scored themselves higher than the researchers, and four teachers scored themselves lower than the researchers. The other two teachers elicited student ideas using visuals or models. Teacher 1 had students build Venn diagrams on whiteboards to generate and display their ideas for group discussion, and Teacher 12 had students move around the room with stick notes, placing their ideas on one another’s projects. However, some teachers rated themselves as Adequate when they were scored as Inadequate by the researchers. Teacher 13’s lesson was rated Inadequate because the lessons included student answers but not elaborations on these answers. Teacher 13’s lesson used analysis questions that did not include probing for reasoning or how students had changed their thinking throughout the lesson. Teacher 14’s lesson used an introductory video at the beginning of the lesson to introduce students to stoichiometry, and
students were asked whether they thought the video was of good quality. This lesson only probed for student opinions on the quality of the video, and only had students show answers for stoichiometry problems in the rest of the lesson.

![Teacher Quality Ratings - Student Ideas](image1.png)  ![Researcher Quality Ratings - Student Ideas](image2.png)

*Figure 17 Teacher Quality Ratings for Generation of Student Ideas*  
*Figure 18 Researcher Quality Ratings for Generation of Student Ideas*

### 6.5.8 Building on Students’ Prior Knowledge

Researcher quality ratings for Building on Students’ Prior Knowledge differed greatly from teacher ratings. Twelve of the lessons were rated as either Adequate or Extensive by teachers, but only seven lessons were rated as Adequate by the researchers. No lessons were rated as extensive in this category by the researchers.
The most common ways that teachers that made use of students’ background knowledge was to use probing classroom discussion prior to activities, or to build upon instruction students received in previous lessons. The researchers were not able to label any of the teacher lessons as Extensive because no lessons truly made use of students’ background knowledge in all Three Dimensions. Most lessons made use of prior knowledge with DCIs and CCCs, but not SEPs. One lesson extensively used students’ SEP skills learned throughout the year but did not adequately make use of DCIs and CCCs. Unfortunately, Teachers 11, 13, and 14 had no evidence of use of students’ prior knowledge. Teacher 2 and Teacher 9 made assumptions about their students’ background knowledge and did not explicitly probe for it in their lessons, however, Teacher 2 listed this mistake as something to be improved upon in the future.
6.6 Discussion

6.6.1 Explaining Phenomena or Designing Solutions

Most teachers in this study were able to place a phenomenon or problem-solving scenario at the center of their lessons, but a few did not do so. For example, Teacher 14’s lesson is meant to introduce students to stoichiometry but is mainly just a problem set. This teacher could build the lesson to revolve around a relevant real-life scenario, such as a pharmaceutical company needing to know how much material is needed to build prescription drugs. This addition could also allow the teacher to expand relevance and authenticity by connecting the lesson to pharmaceutical companies in the community. However, based on responses in this teacher’s EQuIP rubric, they felt that the problem set was satisfactory as a problem-solving scenario. This represents a misconception on the teacher following NGSS PD between practice problems and designing solutions to problems. Additionally, Teacher 11 was not confident enough in her lesson building ability to rate herself as Adequate, even though the researchers scored their lesson as such. It’s possible that this is an example of a teacher who has misconceptions of what constitutes a phenomenon being the purpose and focus of the lesson. In summary, while most teachers tend to understand how to satisfy this portion of the EQuIP rubric, PD practitioners may be advised to be more specific about what does, and what does not, constitute as explaining phenomena or designing solutions to problems.

6.6.2 Use of Three Dimensions: SEPs

The findings from this study suggest that while some teachers do an excellent job incorporating one or more SEP into their NGSS lessons, other teachers may overestimate their abilities. Reiser (2013) noted that some teachers may view the SEPs as equivalent to inquiry, but
with a new name. It seems that some teachers have not adjusted their lessons to adequately address SEPs and are still using the same inquiry-style labs that existed before NGSS. Teacher 10, for example, seems to be using a “cookbook” lab that includes step-by-step procedures that lead students to the answer. Duschl and Bybee (2014) note that while these types of labs may be able to include inquiry, they fail to be truly NGSS-aligned because they do not give students an accurate portrayal of doing science. The 6-8 grade level students participating in Teacher 13’s lesson use a model to analyze and interpret data, but the model is not constructed by students. Both Teacher 10 and Teacher 13’s lessons fall short when it comes to shifts introduced by NGSS in the form of students planning out their own investigations and building their own models. Given these pieces of information, PD practitioners should specifically stress the importance of students building components of their lessons for themselves, under the guidance of their teacher, rather than having the teacher do this for the students.

6.6.3 Use of Three Dimensions: DCIs

While the National Academy of Sciences (2015) point out that use of engineering practices can provide students with engaging experiences for students to increase their understanding of how science works, Osborne (2014) notes that many teachers may not have prior education on engineering practices. Results from Banilower et al.’s (2013) study confirmed that less than 10% of middle and high school teachers are confident in engineering instruction. Given that only one lesson in this study addressed the Engineering Design DCIs, PD practitioners should make a concerted effort to improve teacher training and self-efficacy in building and executing lessons that involve Engineering Design DCIs.
6.6.4 Use of Three Dimensions: CCCs

While most teachers and researchers gave the lessons strong ratings in this category, the frequency amongst teachers scoring themselves as either too high or too low in comparison to the researchers suggests a lack of general understanding of this area of the Three Dimensions. Teacher 5’s evaluation of their lesson on energy transfer for 9-12 students claimed that no CCC was addressed, but upon researcher inspection of the lesson, the Energy and Matter CCC is clearly at the core of the lesson. In contrast, Teacher 1 and Teacher 13 rated their lessons as Adequate for use of Patterns, but justification to satisfy this CCC was minimal at best. The literature does not generally forewarn about teachers lacking understanding of CCCs when attempting to align to NGSS. While there is an abundance of literature that focuses on the need for PD for teachers to improve understanding of the SEPs (Banilower et al., 2013; Bybee, 2011; Osborne, 2014; Shernoff et al., 2017), it is generally assumed that teachers will have an established understanding of the DCIs and CCCs. While the results of this study indicate that teachers tend to be well-versed in their DCI content, teachers may need more PD with regard to understanding and incorporating the CCCs than expected. PD practitioners would be wise not to assume that teachers have the same grasp on CCCs as they have shown with the DCIs.

6.6.5 Integrating the Three Dimensions for Instruction and Assessment

It is difficult for lessons to be ranked highly in this category, as lessons essentially have to score as Extensive in all Three Dimension sub-categories (SEPs, DCIS, CCCs) to be rated as Extensive for Integrating the Three Dimensions for Instruction and Assessment. Additionally, all Three Dimensions must work together, rather than being taught in isolation. This is similar to how students achieve proficiency with the NGSS Performance Expectations (Krajcik, Codere,
Dahsah, Bayer, and Mun, 2014). There was only one submitted lesson that was able to be rated as Extensive in this category. However, nine of the lessons were rated as Adequate, and three lessons were only lacking an Adequate rating in one of the Three Dimension sub-categories. The majority of teachers seem to be doing a quality job with three-dimensional assessment.

6.6.6 Relevance and Authenticity

The fact that the researchers scored only half of the submitted lessons as Adequate for Relevance and Authenticity may be alarming, but possibly easy to explain. Prior to NGSS, relevance to students’ homes, neighborhoods, and communities was welcomed and encouraged in science lessons but was not as much of a priority as it is with NGSS. Teachers have been used to making inquiry and engagement the center of their lessons, so some teachers may struggle to build or modify lessons to ensure all content is related to students’ lives. Several teachers submitted lessons that were well-designed and engaging, and aligned well with most components of NGSS, but fail to have authenticity and relevance to students. Some of these teachers were aware of this and noted confusion as to how to fix this problem in the “suggestions for improvement” section of the EQuIP rubric. This should signal to PD practitioners that while some teachers have shown evidence that they can build and execute NGSS lessons, the inclusion of student relevance may not be at the forefront of their mind while planning. It may be beneficial for PD to guide teachers through a planning process that specifically makes use of examining lessons through the “lens” of student engagement and ensuring that the lesson is relevant to student lives.
6.6.7 Generation of Student Ideas

Comparing teacher and researcher quality ratings for Student Ideas yielded interesting results. Four teachers lacked confidence in their lessons to rate them as Extensive in this category, signaling that some teachers lack self-efficacy in assessing their NGSS lessons using the EQuIP rubric. As Han, Yalvac, Capraro, and Capraro (2015) note, teacher self-efficacy can suffer during the implementation phase of new lessons, even if teachers are doing quality work. Lotter et al. (2016) encourage continued, quality PD to develop teachers with low self-efficacy. However, over-confidence, or perhaps misunderstanding, led other teachers to rate their lessons too highly. One teacher viewed the use of analysis questions that failed to have students demonstrate their own reasoning and learning process, and another teacher gathered student ideas that were related to an introductory video, not the content being learned. These teachers may have misconceptions about their lessons aligning to NGSS, something forewarned by Bybee (2013) as a possibility when teachers initially begin NGSS implementation. Future PD sessions should carefully examine how lessons might have functioned in the past, and how new, NGSS-aligned lessons function. This sort of side-by-side comparison, as suggested by the National Academy of Sciences (2015), would allow teachers to decide what existing lessons need additional revision or possible elimination.

6.6.8 Building on Students’ Prior Knowledge

Incorporating background knowledge into lessons is important for coherence and extended instruction, which are vital components of effective NGSS-aligned instruction (National Research Council, 2012). As pointed out by Krajcik et al. (2014), teachers should no longer be spending a single day or two on a topic then moving onto another, as teaching day-to-day negates coherence (Pruitt, 2014). The lessons submitted by teachers that have no evidence of
probing for background knowledge, or lack evidence of building upon topics and skills learned in prior grades or earlier in the course, are likely lessons that were being used while previous standards were in place that have not been updated or replaced. Kennedy (2016) noted that teachers will enter PD having materials, practices, and habits for classroom management that will compete with new ideas PD presents to them. As pointed out by Johnson (2009), PD practitioners should explicitly build PD to acknowledge teachers’ existing practices and beliefs.

6.7 Conclusion

As pointed out by Kennedy (2016), teachers will need to make dramatic changes to their lessons in order to align with NGSS. Shernoff et al. (2017) note that while teachers have been given PD to assist with modifying their lessons, the quality of the lessons is not well-researched. Teachers in the Channell and Cobern (2018) study reported that they were willing to make changes to their curriculum. Thus, the purpose of this study was to use qualitative data for developing insight on the extent to which teachers are able to produce NGSS-aligned lessons following PD.

The results of this study can be broken down into three main categories: lessons where both the teachers and the researchers scored the majority of lessons as Adequate or Extensive, lessons that saw variability in ratings amongst the teachers and researchers in both negative and positive directions, and lessons where the researchers ranked substantially more lessons as Inadequate than the teachers. The majority of lessons were ranked highly by both teachers and the researchers in the categories of Explaining Phenomena or Designing Solutions, Use of Three Dimensions: SEPs, Use of Three Dimensions: DCIs, and Integrating Three Dimensions for Instruction and Assessment. However, it is worth noting that only one lesson submitted for this
The study utilized Engineering Design DCIs. While this could be due to a relatively low sample size, it is equally likely that this is because teachers generally do not use lessons that incorporate engineering practices in their classroom because of a lack of training or confidence, as supported by Osborne (2014) and Banilower et al. (2013). Engineering-specific PD for teachers is not well-researched (Daugherty, 2009), so further investigation into how engineering practices are incorporated into PD could be performed.

The Use of Three Dimensions: CCCs and Generation of Student Ideas categories were areas where several teachers scored their lessons either higher or lower than the researchers did. These results could have multiple sources. Teachers who rated themselves too low may have inadequate confidence in their lessons in these categories, or a lack of self-efficacy in using the EQuIP rubric. This would suggest the need for additional focus on integrating CCCs and student ideas into lesson plans during PD, and PD that focuses on using the EQuIP rubric to properly self-score lessons. Teachers who rated themselves too highly may have misconceptions about their lessons being NGSS-aligned. Bybee (2013), Huff (2016), and Reiser (2013) all expressed concerns that teachers may underestimate the changes that NGSS brings to science teaching and continue to use similar practices as they did with previous standards. PD practitioners could use this information to structure PD using a side-by-side comparison of what an NGSS-aligned lesson looks like next to an outdated lesson. This would expand upon the explanations of what lessons will look more and less like at the beginning of each section of the EQuIP rubric. A study tracking results in lesson planning pre- and post-PD could be performed to evaluate the PD’s effectiveness in altering teacher predisposition.

An alarming implication from this study is lack of teacher and researcher correlation in quality ratings for the categories of Relevance and Authenticity and Building on Students’ Prior
Knowledge. For both categories, 87.5% of teachers rated their lessons as either Adequate or Extensive, while the researchers only ranked 50.0% of the lessons as Adequate, and no lessons as Extensive. The cause for concern in this situation is that these two categories of the EQuIP rubric are not NGSS shifts, they are features of quality design that are expected from any good science lesson. A possibly implication from this data is that more attention has been placed at the forefront of teachers’ minds, and the forefront of the PD teachers receive, on the NGSS shifts of using phenomena or problem-solving and instructing/assessing with the three dimensions. This information could be useful for both teachers and PD practitioners that while the new NGSS components are important to emphasize while building new lessons or modifying existing lessons, it is important to not forget that what students bring into the classroom should be at the heart of instruction.

6.8 Limitations and Future Work

There are some limitations to this study. One limitation of this study includes the use of teachers in Midwestern districts, preventing the findings from being generalized to other geographic regions. However, teachers did come from a variety suburban, rural, and math and science specific districts. Additionally, PD sessions took place at different points in time (2017 versus 2018) for the participants. Teachers who had undergone PD more recently may have had less time to develop quality lessons that are aligned to NGSS. Finally, some teachers were using the EQuIP rubric for the first time to evaluate their own lessons. During a pilot study conducted with practicing teachers prior to formal research, teachers reported the EQuIP rubric to be easy to use for the first time. However, this does not ensure that all teachers will display initial mastery of the rubric.
The results of this study present implications for future research. In the EQuIP rubric categories of Three Dimensions: CCCs and Generation of Student Ideas, many teachers rated their lessons higher or lower than the researchers. Additionally, in the categories of Relevance and Authenticity and Building on Students’ Prior Knowledge, many teachers scored themselves higher than the researchers did, with half of the lessons being scored as Inadequate by the researchers. Finally, only one lesson made use of the Engineering Design DCIs. These findings suggest a need for PD that is tailored to addressing these components of NGSS-aligned lessons, and a follow-up study on teacher lessons post-PD. Additionally, though, the variability amongst teacher and researcher quality ratings may suggest a lack of understanding or self-efficacy amongst teachers in using the EQuIP rubric to evaluate lessons. PD practitioners may consider adding use of the EQuIP rubric as a component of future PD, and a pre-post PD study on teacher effectiveness using the rubric could evaluate the new PD component.
CHAPTER 7
SUMMARY AND CONCLUSION

NGSS has shifted the landscape of science education to bring many changes for teachers. This collection of manuscripts highlighted challenges for teachers while creating or modifying lessons and learning how to use new classroom management and teaching practices following PD. Additionally, NGSS has brought some frustration for parents, and this study presents perspectives on this situation from both teachers and parents. The following are summaries and conclusions for manuscripts one and two, presented together due to the heavy overlap in their results, and manuscript three, which is related to the first two manuscripts but yields data that has its own independent significance.

7.1 Summary – Manuscripts One and Two

The investigation presented in the first manuscript details teacher opinions on parent awareness and understanding of NGSS, as well as the degree that parents have influenced implementation of NGSS-aligned curricula following PD experiences. The results showed that most teachers in this study said that parents are either uninformed about NGSS or do not know the standards exist at all. Because of this, the feedback teachers reported receiving from parents was not specifically related to NGSS but was evident to be as a result of the changes brought by NGSS. Some parents were concerned with their students struggling due to transitioning to classes that contain more writing and explanation. Others were confused as to how to help with science learning at home due to the lack of assigned homework or an NGSS-aligned textbook (or
any textbook at all, in some cases). Some districts may not have informed parents about NGSS because they are still in the process of full aligning their curriculum, but in the meantime, parents remain in the dark about NGSS.

The study described in the second manuscript provides parent accounts of their awareness and understanding of NGSS, and parent feedback regarding their child’s science education. Parents described themselves as unaware of the existence of NGSS and did not feel that their student’s school district had made an adequate effort to inform them about the NGSS standards reform, and several parents who considered themselves as involved were disappointed about this. However, the majority of parents expressed approval with how science is being taught in school in comparison to their experiences growing up. All of the parents in the study expressed their satisfaction with their child’s science learning due to its “hands-on” nature. However, parents also expressed confusion over the lack of a textbook and homework assigned to their children and felt unsure as to how to help with science at home.

7.2 Summary – Manuscript Three

The third manuscript describes an investigation into NGSS-aligned lessons teachers have built, or heavily modified, to use in their classrooms following PD experiences. Teachers used the EQuIP rubric to self-evaluate their lessons, which was followed by an evaluation of the lessons by the researchers. The different eight areas of the rubric could be categorized based on similarities and differences between the teachers’ and researchers’ ratings. The first category is comprised of components of the rubric that scored well with both the teachers’ self-evaluations and the researchers’ independent evaluations of the lessons, and include Explaining Phenomena or Designing Solutions, Use of Three Dimensions: SEPs, Use of Three Dimensions: DCIs, and
Integrating the Three Dimensions for Instruction and Assessment. While quality ratings in these categories were high, only one submitted lesson contained DCIs for engineering practices. The second category includes rubric components where teacher quality ratings were a mix of higher and lower than those of the researchers, which include Use of Three Dimensions: CCCs and Generation of Student Ideas. Teachers who rated their lessons lower than the researchers could lack an understanding of how to properly integrate CCCs or generate student ideas into their lessons, or they may lack skill using the EQuIP rubric. The third category is made up of portions of the rubric where the researchers scored lessons lower than the teachers’ self-evaluations. These include Relevance and Authenticity and Building on Students’ Prior Knowledge. This may indicate an overconfidence amongst teachers in building lessons that relate to students’ lives and prior knowledge. It is also notable that these two areas of the EQuIP rubric are general components of any good lesson, not shifts required by NGSS. Poor scores in these areas may indicate a need for PD to not only focus on changes that NGSS brings, but also how to integrate those changes with pre-existing features of strong science education.

7.3 Conclusion - Manuscripts One and Two

The studies described in the first and second manuscripts displayed many correlations between teachers and parents, and thus, conclusions formed from both manuscripts are being presented together. Teachers claimed that most parents are not aware of NGSS existing, and any parents that do know that new science standards have been released are not well-informed about them. The responses from parents confirmed the teacher claims, with parents reporting that they essentially know nothing about NGSS. Further, both teachers and parents agreed that school district staff members, including teachers, administrators, and counselors, had done an inadequate job informing parents about NGSS. Regardless of awareness of NGSS, teachers described feedback
from parents about their science instruction as mainly positive and most teachers did not view
parents as a significant hurdle to NGSS implementation. Teachers noted that parents were less
concerned with NGSS and more concerned with their child’s transitions between grade levels
and subjects and the lack of a textbook or homework to allow parents to help their children learn
science outside of school. Parents echoed all of these statements. Parents reported that their
children love their science classes, and also expressed approval that science is being taught
differently than when they were in school, with more “hands-on” activities and fewer lectures
and textbook readings. However, this feedback from parents adds to the evidence that there is a
disconnect between schools and parents about NGSS.

Parents’ use of the phrase “hands-on” to describe their approval of science instruction is
outdated by two sets of standards in 2019, as the National Science Education Standards
(National Research Council, 1996) aimed to build past hands-on activities with inquiry-based
learning, and NGSS seeks to push past inquiry-style learning with science and engineering
practices. Essentially, parents do not understand that the modern goal of science education has
evolved far past having students put their hands on things (Furtak and Penuel, 2018), and that
quality science instruction includes opportunities for students to experience a accurate simulation
of doing science (Duncan and Cavera, 2015).

Parents seem pleased that lectures and textbook readings are not as prevalent in their
children’s science education. However, without things like textbooks or homework coming home
with their children, parents expressed frustration and confusion about how to support science
learning outside of the classroom. Since parents used textbooks and homework when they
learned science in school, these are safe and familiar resources for parents to turn to when
looking to help their children with science at home. Some districts do not have NGSS-aligned
textbooks yet because they are waiting to purchase the ideal books following the completion of a science curriculum overhaul, but many schools have moved on from science textbooks altogether (Channell and Cobern, 2018). Parents are simply not aware of this situation with textbook or the reasoning behind it. Additionally, many of the changes to science education that NGSS brings, such as explaining phenomena, problem-solving, argumentation, and building explanations, tend to happen within the classroom. These activities are typically not independent activities for students, and often don’t always translate well into homework worksheets or study guides.

Assessments now require students to form answers based on evidence and explain the evolution of their thought process (National Research Council, 2012), making more traditional rote-memorization assessments a thing of the past. As Teacher 6 from the first study explained, “I think with the parents, they want their kid, you know, the night before a test, to have a whole drill and kill. Like, this is exactly what the test is going to be. And so, working with phenomenon, it’s hard to come up with like, 20 new phenomena for them to explain. Because all of our tests are about, explain this new scenario with knowledge that you already have.” Based on parent responses from the second study, parents are not aware of this situation regarding assessment.

Districts need to inform parents about the improvements NGSS makes over science standards of the past and “hands-on” learning, and also what changes NGSS brings for the children both inside and outside of the classroom. The NGSS website includes pre-made resources for parents to help understand these changes (Achieve, 2017). As a first step, these documents could be shared directly with parents, or modified to be tailored to a district’s approach to NGSS and then shared. Additionally, parents need tools to help their children with science at home. (Silander et al., 2018) suggest that use of media can help parents understand what science is, what it looks
like, and why it’s important for students. Teachers from the first study also suggested that social media, such as Facebook or Instagram, could become tools to share what’s going on in class with parents and stimulate science-centered conversations at home. Teacher 9 from the first study felt that parents could actually be empowered to continue NGSS-style conversations at home: “I think that parents can have conversations with kids to promote the NGSS-type of thinking, you know, more questioning at home, and not always giving them answers. Kind of letting them find out on their own. I think that type of conversation with kids would be really helpful in the way that we’re trying to instruct and teach. And I think education with parents, just kind of like, let them come to their own answers. Say, “that’s a cool idea”, and you know, don’t correct them all the time. That would be powerful, especially for the lower-level kids.” This would present opportunities for parents to help their students learn science, as parents reported they wished to do in Silander et al.’s (2018) study. With a better understanding of NGSS, parents could be empowered to act as a source of science-centered conversation about situations at home and in the community.

7.4 Conclusion – Manuscript Three

The third study did not present significant connections with the first and second studies. Based on teacher feedback gathered from Channell and Cobern’s (2018) study, it was inferred by the researchers that there could be a possible correlation between the quality of NGSS lessons teachers created following PD and feedback from parents about their child’s learning. This was not the case. While some parents were concerned their child’s learning being affected by the transition between grade levels and subjects, parents did not report concerns with the quality of lessons that teachers used. In fact, the majority of parents expressed approval of the different
methods science teachers were using in their classrooms, especially compared to those that parents recalled experiencing during their years in school. While this study does not show a connection to the first and second studies, it does provide a number of relevant pieces of information for PD practitioners to improve future NGSS PD experiences for teachers. Science practices within the Three Dimensions: SEPs were evident and ranked well for quality amongst the majority of lessons, and the DCIs relating to science topics such as life science and physical science were well-represented. However, engineering practices and DCIs for engineering were not well represented in the study, with only one lesson making explicit use of these portions of the rubric. Studies by Banilower et al. (2013) and Shernoff, Sinha, Bressler, and Schultz (2017) both showed teachers lacked confidence and skills to teach engineering concepts. Teachers need engineering-specific PD to increase their understanding and self-efficacy in building and incorporating engineering lessons into their classrooms. Additionally, there were categories of the EquIP rubric where teachers rated themselves either too high or too low. This could indicate confusion about these areas. Osborne (2014) notes that teachers may have mastered the science content found in the DCIs, but teachers will have less training to develop knowledge of the SEPs. However, the results of this study suggest that understanding the CCCs seem to also be an area where teachers struggle. Finally, teachers scored their lessons too high in the Relevance and Authenticity and Building on Students’ Prior Knowledge categories of the EquIP rubric. Some authors have forewarned that teachers may be overconfident that their existing lessons are NGSS-aligned (Huff, 2016; Reiser, 2013). Interestingly though, these two components of the EquIP rubric are not NGSS shifts, but rather general features of quality instruction. This implies that teachers and PD practitioners may be focusing so much on the aligning lessons to NGSS shifts, basic features of good educational experiences for students are being ignored. PD needs to
focus on the changes that NGSS brings but also demonstrate how teachers can provide students with meaningful experiences that relate to their experiences and prior knowledge.
REFERENCES


APPENDIX A – Teacher Survey Tool and Teacher Interview Tool

Teacher Survey Tool

Thank you for taking the time to complete this survey. The purpose of this survey is to better understand educator experiences during the transition to the Next Generation Science Standards (NGSS) in regard to parents. The survey is approximately 10-15 minutes in length. Your responses are completely confidential.

If you have any questions about this survey contact Adam Channell at adam.c.channell@wmich.edu.

Your participation is greatly appreciated!

*Please answer the following questions to the best of your ability.*

Please list the district in which you currently teach: ______________________

Please list the subject(s) which you currently teach: ______________________

Please select grade band(s) that you teach:
- [ ] 9-12
- [ ] 6-8
- [ ] 3-5
- [ ] K-2

Please select the range of full-time teaching experience you currently have:
- [ ] 0-4 years
- [ ] 5-10 years
- [ ] 10-15 years
- [ ] 15+ years

The parents within your school are aware of the Next Generation Science Standards (NGSS).
- [ ] Strongly Agree
- [ ] Agree
- [ ] Disagree
- [ ] Strongly Disagree
The parents within your school are well informed about NGSS.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

Your school’s administration has done a quality job informing parents about NGSS.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

Your school’s counselors have done a quality job informing parents about the NGSS.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

You, as a teacher, have done a quality job informing parents about the NGSS.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

If the any of the staff within your school, including you, have made attempts to inform parents about NGSS, please describe how: _____________________________.

You have received positive feedback from parents regarding the use of NGSS while teaching.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

If you have received positive feedback from parents regarding use of NGSS, please elaborate: __________________

You have received negative feedback from parents regarding the use of NGSS while teaching.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

If you have received negative feedback from parents regarding use of NGSS, please elaborate: __________________

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Parents have made implementation of NGSS more challenging.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

If you feel parents have made implementation of NGSS more challenging, please elaborate:
_____________________________

I feel that parents are aware of where to find resources for parents to better understand NGSS.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

I feel there are adequate available resources for parents to better understand NGSS.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

Please describe any experiences you have had with parents regarding NGSS that you have not already addressed in previous questions: _____________________________

Please describe any ways you would improve your current situation regarding parent understanding of NGSS: _____________________________

Thank you for taking this survey. If there are any additional comments you’d like to add that were not addressed, please do so here: ___________________________________

Teacher Interview Tool

*Please answer the following questions to the best of your ability.*

In what district do you currently teach?

What subject(s) do you currently teach?

What grade band(s) do you currently teach?

How many years have you been teaching full-time?

Do you feel that parents within your school are aware of the Next Generation Science Standards (NGSS)?
Do you feel the parents within your school are well informed about NGSS?

Describe any attempts you, or other staff in your building (administration, counselors), have made to inform parents about NGSS.

Describe the type of feedback you have received from parents since implementing NGSS into your classroom.

Describe any challenges introduced by parents you have experienced while implementing NGSS into your classroom.

Do you feel that parents are aware of the available resources to inform them about NGSS?

If so, do you feel these resources for parents are adequate?

Please describe any experiences you have had with parents regarding NGSS that you have not already addressed in previous questions.

Please describe any ways you would improve your current situation regarding parent understanding of NGSS.

Thank you for participating in this interview. If there are any additional comments you’d like to add that were not addressed, please do so.
APPENDIX B - Codebook for Teacher Survey and Interview Questionnaires

1 - Teacher perceptions of parent awareness of NGSS

1a - Teachers feel that parents are unaware NGSS exists.

1b - Teachers feel that school staff have not done a quality job of informing parents about NGSS.

1c - Teachers feel that parents are unaware of where to find the resources available for parents to learn about NGSS.

2 - Teacher accounts of parent feedback and concerns

2a - The majority of teachers reported no interaction with parents about NGSS.

2b - If teachers receive feedback from parents about their classroom activities, it is positive.

2c - Teachers felt parents were more concerned with whether transitional periods were smooth for their students.

2d - Teachers received feedback from parents about the lack of a textbook and being unsure as to how to help their student with science schoolwork at home.

2e - Teachers only tend to experience pushback from parents if they feel their student is not learning.

3 - Teacher suggestions for improving parent understanding of NGSS

3a - Teachers offered several suggestions for improving parent understanding of NGSS.

3b - Some districts are preparing for a formal rollout to parents of their new NGSS-aligned curricula in an effort to inform parents of how science teaching is changing.
APPENDIX C - EQuIP Rubric for Rating Teacher Lessons

Introduction
The purpose of the Next Generation Science Standards (NGSS) Lesson Screener is to quickly review a lesson to see: (1) whether a lesson being developed or revised is on the right track; (2) if a lesson warrants further review using the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for Lessons & Units: Science (see further detail below); and (3) to what extent a group of reviewers have a common understanding of the NGSS or designing lessons for the NGSS. There is a recognition among educators that curriculum and instruction will need to shift with the adoption of the NGSS, but it is currently difficult to find lessons that are truly designed for the NGSS rather than just connecting existing lessons to the standards. The power of the lesson screener is in the productive conversations educators have while evaluating materials (i.e., the review process). Even with high-quality materials, teachers use their professional judgement in selecting and shaping lessons in their classrooms. For the purposes of using the lesson screener, a lesson is defined as a coherent set of instructional activities and assessments that may extend over several class periods or days; it is not just a single activity.

The directions for using the lesson screener assume an understanding of A Framework for K-12 Science Education and the NGSS, including how the NGSS are different from past standards as outlined in Appendix A of the NGSS. Some of these “NGSS Shifts” are described in criteria A–C of this tool, whereas criteria D–F of this tool describe other features of high-quality lesson design. It is also very helpful to be familiar with how each of the three dimensions of the NGSS differ between grade bands.

Users who are familiar with the EQuIP Rubric will recognize some familiar criteria. However, the NGSS Lesson Screener has fewer criteria because the intended purpose is different and smaller in scope—it is only for lessons and not for units, and it is not intended to fully evaluate and score lessons. There are significant aspects of what would be expected in an NGSS-designed lesson that are not addressed in this tool. The lesson screener should not be used to fully vet resources and its use is not sufficient to claim that the lessons are fully designed for the NGSS. The EQuIP Rubric for Science should be used to evaluate NGSS design for lessons and units and the Primary Evaluation of Essential Criteria (PEEC) should be used for evaluating full curricula or instructional materials programs.

Using the NGSS Lesson Screener: A Quick Look at Potential NGSS Design
Providing criterion-based feedback and suggestions for improvement to the developer of the lesson under review is important to the review process. For this purpose, a set of response forms is included for each category on the following pages. Evidence for each criterion must be identified and documented. In addition, criterion-based feedback and suggestions for improvement should be given to help improve the lesson.

While it is possible for the rubric to be applied by an individual, the quality review process works best with a team of reviewers as a collaborative process. Just as when using the full EQuIP Rubric for Science, users should:
1) individually record criterion-based evidence,
2) individually make suggestions for improvement, and then
3) collaboratively discuss findings with team members before checking one of the boxes under the “Evidence of Quality?” column. A rating of “Adequate” means that the lesson meets the criterion.

Working as a group will not only result in a better lesson, but can also bring the group to a common and deeper understanding of designing lessons for the NGSS.
NGSS Lesson Screener
A Quick Look at Potential NGSS Lesson Design for Instruction and Assessment

The lesson is designed to engage all students in making sense of phenomena and/or designing solutions to problems through student performances that integrate the three dimensions of the NGSS.

<table>
<thead>
<tr>
<th>NGSS Shifts</th>
<th>Features of Quality Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Explaining Phenomena or Designing Solutions: The lesson focuses on supporting students to make sense of a phenomenon or design solutions to a problem.</td>
<td></td>
</tr>
<tr>
<td>B. Three Dimensions: The lesson helps students develop and use multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs), which are deliberately selected to aid student sense-making of phenomena or designing of solutions.</td>
<td></td>
</tr>
<tr>
<td>C. Integrating the Three Dimensions for Instruction and Assessment: The lesson requires student performances that integrate elements of the SEPs, DCIs, and CCCs to make sense of phenomena or design solutions to problems, and the lesson elicits student artifacts that show direct, observable evidence of three-dimensional learning.</td>
<td></td>
</tr>
<tr>
<td>D. Relevance and Authenticity: The lesson motivates student sense-making or problem-solving by taking advantage of student questions and prior experiences in the context of the students' home, neighborhood, and community as appropriate.</td>
<td></td>
</tr>
<tr>
<td>E. Student Ideas: The lesson provides opportunities for students to express, clarify, justify, interpret, and represent their ideas (i.e., making thinking visible) and to respond to peer and teacher feedback.</td>
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</tr>
<tr>
<td>F. Building on Students’ Prior Knowledge: The lesson identifies and builds on students’ prior learning in all three dimensions in a way that is explicit to both the teacher and the students.</td>
<td></td>
</tr>
</tbody>
</table>
Criterion A. Explaining Phenomena or Designing Solutions

1. Learn about the importance of explaining phenomena and designing solutions in lessons designed for the NGSS here: www.nextgenscience.org/phenomena. Once you are comfortable with the role of explaining phenomena and designing solutions, use the table below to help gather evidence that either student problem-solving or sense-making of phenomena drives the lesson:

<table>
<thead>
<tr>
<th>Explaining Phenomena or Designing Solutions</th>
<th>NGSS designed lessons will look less like this:</th>
<th>NGSS designed lessons will look more like this:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explaining phenomena and designing solutions are not a part of student learning or are presented separately from “learning time” (i.e., used only as a “hook” or engagement tool, used only for enrichment or reward after learning; only loosely connected to a DEE).</td>
<td>The purpose and focus of the lesson are to support students in making sense of phenomena and/or designing solutions to problems. The entire lesson drives toward this goal.</td>
<td></td>
</tr>
<tr>
<td>The focus is only on getting the “right” answer to explain the phenomenon.</td>
<td>Student sense-making of phenomena and designing of solutions is used as a window into student understanding of all three dimensions of the NGSS.</td>
<td></td>
</tr>
<tr>
<td>A different, new, or unrelated phenomenon is used to start every lesson.</td>
<td>Lessons work together in a coherent storyline to help students make sense of phenomena.</td>
<td></td>
</tr>
<tr>
<td>Teachers tell students about an interesting phenomenon or problem in the world.</td>
<td>Students get direct (promptly, firsthand, or through media representations) experience with a phenomenon or problem that is relevant to them and is developmentally appropriate.</td>
<td></td>
</tr>
<tr>
<td>Phenomena are brought into the lesson after students develop the science ideas so students can apply what they learn.</td>
<td>The development of science ideas is anchored in explaining phenomena or designing solutions to problems.</td>
<td></td>
</tr>
</tbody>
</table>

2. Record evidence about how explaining phenomena or designing solutions to problems are represented in the lesson. Describe in the response form below how this evidence is or is not an adequate indicator the criterion is being met. Include detailed suggestions for improvement.

<table>
<thead>
<tr>
<th>Lessons designed for the NGSS include clear and compelling evidence of the following:</th>
<th>What was in the materials, where was it, and why is this evidence?</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Explaining Phenomena or Designing Solutions:</td>
<td></td>
<td>□ None</td>
<td>□ Adequate</td>
</tr>
<tr>
<td>The lesson focuses on supporting students to make sense of a phenomenon or design solutions to a problem.</td>
<td></td>
<td>□ inadequate</td>
<td>□ Extensive</td>
</tr>
</tbody>
</table>

3. If you are working in a group, compare lists of evidence and reasoning and come to consensus about whether this lesson met Criterion A.
**Criterion B. Three Dimensions**

1. **Document evidence of specific grade-banded elements** of each dimension—including what evidence was in the lesson, where it occurs, and why it should be considered to be evidence. To be considered as evidence, it should be clear how the student learning will develop or apply a specific element in a way that distinguishes it from other grade bands. Use the table below to help gather evidence about how each dimension is used in this lesson:

<table>
<thead>
<tr>
<th>NGSS designed lessons will look less like this:</th>
<th>NGSS designed lessons will look more like this:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A single practice element shows up in the lesson.</td>
<td>The lesson helps students use multiple (e.g., 2–4) practice elements as appropriate in their learning.</td>
</tr>
<tr>
<td>The lesson focuses on isolated definitions of the practice or crosscutting concepts, names such as “causal relationships,” “cause and effect,” rather than on grade-appropriate learning goals (e.g., elements in NGSS Appendices F &amp; G).</td>
<td>Specific grade-appropriate elements of SEP and CCCs (from NGSS Appendices F &amp; G) are specified, illustrated, or used by students to help explain phenomena or solve problems during the lesson.</td>
</tr>
<tr>
<td>The SEP and CCCs can be inferred by the teacher (not necessarily the students) from the lesson materials.</td>
<td>Teachers explicitly use the SEP and CCC elements to make sense of the phenomenon or to solve a problem.</td>
</tr>
<tr>
<td>Engineering lessons focus on trial-and-error activities that don’t require science or engineering knowledge.</td>
<td>Engineering lessons require students to acquire and use elements of DCIs from physical, life, or earth and space science together with elements of DCIs from engineering design (ED) to solve design problems.</td>
</tr>
</tbody>
</table>

2. **Record specifically where you find each dimension in the lesson.** Describe in the response form below how this evidence is or is not an adequate indicator of the criterion being met. Include detailed suggestions for improvement.

<table>
<thead>
<tr>
<th>Lessons designed for the NGSS include clear and compelling evidence of the following:</th>
<th>What was in the materials, where was it, and why is this evidence?</th>
<th>Overall Evidence of Quality?</th>
<th>Suggestions for Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Three Dimensions: The lesson helps students develop and use multiple grade-appropriate elements of the science, and engineering practices (SEP), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) which are deliberately selected to aid student sense-making of phenomena or designing of solutions.</td>
<td>Document evidence for each dimension.</td>
<td>None</td>
<td>Inadequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inadequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extensive</td>
</tr>
</tbody>
</table>

3. If you are working in a group, compare lists of evidence and reasoning and come to consensus about whether this lesson met Criterion B.
**Criterion C. Integrating the Three Dimensions for Instruction and Assessment**

1. **Learn more about the importance of the three dimensions working together** in this brief paper. Then, use your evaluation of the lesson for criterion B (three dimensions) to examine the lesson for places that students use the three dimensions together to explain a phenomenon or design a solution to a problem. Use the table below to help gather evidence about three-dimensional learning and assessment in the lesson:

<table>
<thead>
<tr>
<th>Integrating the Three Dimensions</th>
<th>NGSS designed lessons will look like this:</th>
<th>NGSS designed lessons will look more like this:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students learn the three dimensions in isolation from each other (e.g., a separate lesson or activity on science methods followed by a later lesson on science knowledge).</td>
<td>• The lesson is designed to build student proficiency in at least one grade-appropriate element from each of the three dimensions.</td>
<td>Teachers deliberately seek out student artifacts that show direct, observable evidence of learning, building toward all three dimensions of the NGSS at a grade-appropriate level.</td>
</tr>
<tr>
<td>Teachers assume that correct answers indicate student proficiency without the student providing evidence or reasoning.</td>
<td>• The three dimensions intentionally work together to help students explain a phenomenon or design solutions to a problem.</td>
<td>All three dimensions are necessary for sense-making and problem solving.</td>
</tr>
<tr>
<td>Teachers measure only one dimension at a time (e.g., separate items for measuring SEPs, DCIs, and CCCs).</td>
<td>• All three dimensions are necessary for sense-making and problem solving.</td>
<td>Teachers use tasks that ask students to explain phenomena or design solutions to problems, and that reveal the level of student proficiency in all three dimensions.</td>
</tr>
</tbody>
</table>

2. **Record evidence** about how the three dimensions are integrated for instruction and assessment purposes. Describe in the response form below how this evidence is or is not an adequate indicator the criterion is being met. Include detailed suggestions for improvement.

<table>
<thead>
<tr>
<th>Lessons designed for the NGSS include clear and compelling evidence of the following:</th>
<th>What was in the materials, where was it, and why is this evidence?</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Integrating the Three Dimensions for instruction and Assessment: The lesson requires student performances that integrate elements of the SEPs, CCCs, and DCIs to make sense of phenomena or design solutions to problems, and the lesson elicits student artifacts that show direct, observable evidence of three-dimensional learning.</td>
<td></td>
<td>□ None  □ Inadequate  □ Adequate  □ Extensive</td>
<td></td>
</tr>
</tbody>
</table>

3. **If you are working in a group, compare lists of evidence and reasoning and come to consensus about whether this lesson met Criterion C.**
Criterion D. Relevance and Authenticity

1. Learn about the importance of making lessons relevant and authentic for all students in NGSS Appendix D. Once you are comfortable with ideas for making lessons relevant and authentic for all students, examine the lesson through the "lens" of student engagement, and for clear evidence that the lesson supports connections to students’ lives. Use the table below to help gather evidence about the relevance and authenticity of the lesson for students:

<table>
<thead>
<tr>
<th>Relevance and Authenticity</th>
<th>NGSS designed lessons will look less like this:</th>
<th>NGSS designed lessons will look more like this:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lesson teaches a topic adults think is important.</td>
<td>The lesson motivates student sense-making or problem-solving.</td>
<td></td>
</tr>
<tr>
<td>The lesson focuses on examples that some students in the class understand.</td>
<td>The lesson provides support to teachers for making connections to the lives of every student in the class.</td>
<td></td>
</tr>
<tr>
<td>Driving questions are given to students.</td>
<td>Student questions, prior experiences, and diverse backgrounds related to the phenomenon or problem are used to drive the lesson and the sense-making or problem-solving.</td>
<td></td>
</tr>
<tr>
<td>The lesson tells the students what they will be learning.</td>
<td>The lesson provides support to teachers or students for connecting students’ own questions to the targeted materials.</td>
<td></td>
</tr>
</tbody>
</table>

2. Record evidence about how the lesson is relevant to students and motivates their learning. Describe in the response form below how this evidence is or is not an adequate indicator the criterion is being met. Include detailed suggestions for improvement:

<table>
<thead>
<tr>
<th>Lessons designed for the NGSS include clear and compelling evidence of the following:</th>
<th>What was in the materials, where was it, and why is this evidence?</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. Relevance and Authenticity: The lesson motivates student sense-making or problem-solving by taking advantage of student questions and prior experiences in the context of the students’ home, neighborhood, and community as appropriate.</td>
<td></td>
<td>□ None □ inadequate □ Adequate □ Extensive</td>
<td></td>
</tr>
</tbody>
</table>

3. If you are working in a group, compare lists of evidence and reasoning and come to consensus about whether this lesson met Criterion D.
**Criterion E. Student Ideas**

1. **Examine the lesson for opportunities for all students to communicate their ideas** and for the depth to which student ideas are made visible. Use the table below to help gather evidence about how each dimension is used in this lesson:

<table>
<thead>
<tr>
<th>Student Ideas</th>
<th>NGSS designed lessons will look like this:</th>
<th>NGSS designed lessons will look more like this:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The teacher is the central figure in classroom discussions.</td>
<td>Classroom discourse focuses on explicitly expressing and clarifying student reasoning.</td>
</tr>
<tr>
<td></td>
<td>Student artifacts only show answers.</td>
<td>Students have opportunities to share ideas and feedback with each other directly.</td>
</tr>
<tr>
<td></td>
<td>The teacher’s guidance focuses on what to tell the students.</td>
<td>Student artifacts include elaborations (which may be written, oral, pictorial), and a narrative of reasoning behind their answers, and show how students’ thinking has changed over time.</td>
</tr>
</tbody>
</table>

2. **Record evidence** about how student ideas are elicited from ALL students during the lesson. Describe in the response form below how this evidence is or is not an adequate indicator the criterion is being met. Include detailed suggestions for improvement.

<table>
<thead>
<tr>
<th>Lessons designed for the NGSS include clear and compelling evidence of the following:</th>
<th>What was in the material, where was it, and why is this evidence?</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. Student Ideas: The lesson provides opportunities for students to express, clarify, justify, interpret, and represent their ideas (i.e., making thinking visible) and to respond to peers and teacher feedback.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. If you are working in a group, **compare lists of evidence and reasoning and come to consensus** about whether this lesson met Criterion E.
**Criterion F. Building on Students’ Prior Knowledge**

1. **Learn about the expected learning progressions of each of the three dimensions** in NGSS Appendices E, F, and G. Once you are familiar with the learning progressions, use the table below to help gather evidence about how the lesson builds on students’ prior learning in each of the three dimensions:

<table>
<thead>
<tr>
<th>Building on Students’ Prior Knowledge</th>
<th>NGSS designed lessons will look less like this</th>
<th>NGSS designed lessons will look more like this</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The lesson content builds on students’ prior learning, but only for DQs.</td>
<td>The lesson content builds on students’ prior learning in all three dimensions.</td>
</tr>
<tr>
<td></td>
<td>The lesson does not include support to teachers for identifying students’ prior learning.</td>
<td>The lesson provides explicit support to teachers for identifying students’ prior learning and accommodating different entry points, and describes how the lesson builds on the prior learning.</td>
</tr>
<tr>
<td></td>
<td>The lesson assumes that students are starting from scratch in their understanding.</td>
<td>The lesson explicitly works together with students’ foundational knowledge and practice from prior grade levels.</td>
</tr>
</tbody>
</table>

2. **Record evidence** about how the lesson builds on students’ prior learning. Describe in the response form below how this evidence is or is not an adequate indicator the criterion is being met. Include detailed suggestions for improvement.

<table>
<thead>
<tr>
<th>Lessons designed for the NGSS include clear and compelling evidence of the following:</th>
<th>What was in the materials, where was it, and why is this evidence?</th>
<th>Evidence of Quality?</th>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>F. Building on Students’ Prior Knowledge: The lesson identifies and builds on students’ prior learning in all three dimensions in a way that is explicit to both the teacher and students.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. If you are working in a group, **compare lists of evidence and reasoning and come to consensus** about whether this lesson met Criterion F.
APPENDIX D – Parent Survey Tool and Parent Interview Tool

Parent Survey Tool

Thank you for taking the time to complete this survey. The purpose of this interview is to better understand how parents can best be supported during their child’s transition to the Next Generation Science Standards. The survey is approximately 10-15 minutes in length. Your responses are completely confidential.

If you have any questions about this survey contact Adam Channell at adam.c.channell@wmich.edu.

Your participation is greatly appreciated!

The Next Generation Science Standards were published in 2013. Since then, teachers have been receiving professional development to aid in their implementation in your child’s science classroom.

Please answer the following questions with the response you most identify with.

Select your highest level of education:

☐ Some high school
☐ High school diploma or GED
☐ Some college
☐ Associates degree
☐ Bachelors degree
☐ Masters degree
☐ Doctoral degree

Please list the district in which your child (or children) attend school: ______________________

Does your child (or children) qualify for free or reduced lunch?

☐ Yes
☐ No

Your child’s school staff (teachers, administration, or counselors) have done a quality job informing you about the Next Generation Science Standards.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree
If your child’s school staff has made an attempt to inform you about the Next Generation Science Standards, please describe how: _____________________________.

I am aware of where to find resources for parents to better understand the Next Generation Science Standards.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree

Do you feel your child is aware of the Next Generation Science Standards?

☐ Yes
☐ No
☐ Unsure

Has your child expressed to you that they are learning using the Next Generation Science Standards?

☐ Yes
☐ No

How do the Next Generation Science Standards affect your child’s ability to learn science in class?

☐ The standards make learning much easier.
☐ The standards make learning easier.
☐ The standards have had no effect on my child’s ability to learn.
☐ The standards make learning more difficult.
☐ The standards make learning much more difficult.

How have the Next Generation Science Standards affected your ability to help your child with their homework?

☐ The standards make helping with homework much easier.
☐ The standards make helping with homework easier.
☐ The standards have had no effect on helping my child with homework.
☐ The standards make helping with homework more difficult.
☐ The standards make helping with homework much more difficult.

Your child’s experiences with the Next Generation Science Standards are an improvement over how you learned science in school.

☐ Strongly Agree
☐ Agree
☐ Disagree
☐ Strongly Disagree
☐ Unsure
The Next Generation Science Standards will positively affect your child when they graduate high school.

- □ Strongly Agree
- □ Agree
- □ Disagree
- □ Strongly Disagree
- □ Unsure

Thank you for taking this survey. If there are any additional comments you’d like to add that were not addressed, please do so here. ____________________________

Parent Interview Tool

The Next Generation Science Standards were published in 2013. Since then, teachers have been receiving professional development to aid in their implementation in your child’s science classroom.

Please answer the following questions to the best of your ability.

Tell me what you know about the Next Generation Science Standards.

Tell me about how you learned about the Next Generation Science Standards.

Discuss how your child’s school has informed you about the Next Generation Science Standards.

Describe an experience regarding your child’s science education you feel affected your child.

Do you find difficulties in helping your child do their science homework?

Think about your science education as a child. Tell me about how you think your child’s experiences with the Next Generation Science Standards are different than how you learned science in school.

Tell me about the communication between you and your child’s teacher.

How do you think the Next Generation Science Standards will affect your child when they graduate high school?

Thank you for participating in this interview. If there are any additional comments you’d like to add that were not addressed, please do so.
APPENDIX E - Codebook for Parent Survey and Interview Questionnaires

1 - Parent awareness of NGSS

1a - Parents report that they are unaware that NGSS exist.

1b – Parents feel their child’s school staff have not done an adequate job informing parents about NGSS.

2 - Parent feedback

2a - Parents know that science teaching had changed since they were students.

2b - Parents are pleased with the instruction their children receive.

2c - Parents consistently equated good science teaching to being “hands-on”.

2d - Parents feel that their children appreciate science more because of their instruction.

3 - Parent concerns

3a – Parents are concerned with grades and learning suffering due to new science teaching practices.

3b - Parents felt confused and uneasy about the lack of a textbook and homework in their children’s science classes.
APPENDIX F - HSIRB Approval Letter for Teacher Studies

Date: October 11, 2018

To: Bill Cobern, Principal Investigator
   Adam Channell, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 18-09-42

This letter will serve as confirmation that your research project titled “Teachers’ Perspective on the Extent to which parents Influence NGSS Implementation/An Analysis of Teacher-Created NGSS-Aligned Materials” has been approved under the expedited category of review by the Western Michigan University Institutional Review Board (IRB). The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may only be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., you must request a post-approval change to enroll subjects beyond the number stated in your application under “Number of subjects you want to complete the study”). Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: October 10, 2019
Date: October 4, 2018

To: Bill Cobern, Principal Investigator
    Adam Channell, Student Investigator

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 18-09-43

This letter will serve as confirmation that your research project titled “Parent Accounts of Understanding and Support for NGSS” has been approved under the expedited category of review by the Western Michigan University Institutional Review Board (IRB). The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may only be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., you must request a post-approval change to enroll subjects beyond the number stated in your application under “Number of subjects you want to complete the study”). Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: October 3, 2019