Appendix G. Submission Form for Final Dissertation Document

(Send to Dissertation Committee Chair)

This form certifies the dissertation committee has approved the defense of this dissertation and signify all required corrections or adjustments have been made and reviewed according to policy and expectations. This form is to accompany the submission of the dissertation to the student's portfolio and to the Librarian for uploading to the Library database.

The document meets APA 6th Edition style requirements: Dr. Elizabeth Johnson
Signature of Reviewer

I, Milton G. Harris, have made all the corrections and/or adjustments
Print Full Name of Student

required by my dissertation committee. I have also adhered to and followed all style requirements for formatting.

Milton Harris 6/20/2018
Signature of Student *Date*

This is to certify my final review of this student's corrections and/or adjustments to the dissertation as required by the dissertation committee. The document adheres to the APA 6th Edition. I approve the submission of this dissertation to be housed in the Library database.

Imani Akin, EDD June 20, 2018
Signature of Committee Chair *Date*

Examining Middle School Teacher Perceptions of the Next Generation Science Standards: A Qualitative Study

by

Milton G. Harris

Dissertation Submitted to the Doctoral Program

of the American College of Education

in partial fulfillment of the requirements for the degree of

DOCTOR OF EDUCATION

June 2018

Examining Middle School Teacher Perceptions of the

Next Generation Science Standards:

A Qualitative Study

by

Milton G. Harris

Approved by:

Dissertation Chair:	Dr. Imani Akin
Committee:	Dr. Francoise Bachelor
	Dr. Bridgette Davis
Program Chair:	Dr. Crystal Neumann
Asst. Provost:	Dr. Jerry Ausburn

Abstract

Science education in the US entered a period of reform in 2011 with the development and implementation of the Next Generation Science Standards (NGSS). The NGSS have subsequently been adopted in 18 states. School districts within these states are in the process of adjusting science curricula to align with the academic expectations described by the standards. Science teachers' perceptions have implications for the kinds of inquiry-based teaching employed in science classrooms. This dissertation examines middle school science teachers' perceptions of the NGSS. The research questions designed for this study address teachers' perceptions of (1) the 'seven conceptual shifts' proposed by the NGSS, (2) the resources and support systems provided for NGSS implementation, and (3) challenges to implementing the NGSS. A constructivist grounded theory methodology was used to explore these research questions. Data were collected from surveys and semi-structured interviews with teachers, and actual science lessons used by teachers. Teachers' perceptions of the NGSS were mostly consistent with the seven conceptual shifts expected during NGSS implementation. Sustained, relevant, professional development, collaboration with colleagues, availability of NGSS aligned resources, and flexible learner-centered classrooms were among the things teachers reported to be most beneficial during NGSS implementation. Teachers also reported barriers to implementation, including confusion regarding the organization of the standards, varying interpretations of the standards, insufficient time for proper implementation, and science teachers' personal expectations. This study provides insights regarding how pre-service educators, education leaders, and policymakers can best support middle school science teachers in implementing the NGSS.

Dedication

This dissertation is dedicated to all the creative, hardworking, and resourceful science educators who are invested in making science enjoyable, relevant, and applicable to the lives of students.

Acknowledgments

This dissertation would not have been possible without the support and guidance of my dissertation chair, Dr. Imani Akin. Dr. Akin supported me to the fullest with her vast knowledge of the doctoral process and consistent encouragement over the last several years. There were many times during which I wanted to give up, but decided to continue due to her encouragement and unwavering belief in my abilities. Thank you, Dr. Akin.

I would also like to thank my committee members Dr. Bridgette Davis and Dr. Francoise Bachelor who provided valuable scholarly feedback and advice throughout the development of this dissertation.

Finally, I would also like to acknowledge my good friend Reginald Chapple of Calera, Alabama for providing constant support and encouragement throughout this process.

Table of Contents

List of Tables

Table

List of Figures

Figure

Chapter 1: Introduction

Former President Barack Obama presented his thoughts on science in an address to student participants of the White House Science Fair in 2015. He identified science as being more than a set of principles or ideas which are combined to create a discipline. The former president explained science is a way of understanding the world which involves exploration, engagement, and critical thinking (The White House Office of the Press, 2015). These actions contrast with traditional teacher-centered methods of teaching and learning which have been canonized throughout the history of science education (Morrison, 2014). The former president further posited science is an enterprise for everyone, and this notion should be reflected and reinforced in our nation's classrooms (The White House Office of the Press, 2015).

Barack Obama's vision for science education cannot be applied until teachers use more learner-centered instructional approaches involving active learning. Students who are involved actively in the learning process tend to retain more of what is learned. Students who are engaged in active learning are also able to apply the learned knowledge broadly to problems of relative importance and significance (Waldrop, 2015). This implies students will recognize connections between what is learned in the science classroom and the outside world and will be able to utilize the skills learned in science classes to address practical problems of daily living (McFarlane, 2013). The Next Generation Science Standards (NGSS) are a set of curriculum guidelines developed collaboratively by U. S. education bodies to address the need for change in how science is taught in U. S. schools from kindergarten to 12th grade K-12 schools.

Background of the Study

The K-12 education system is in transition as efforts are being made to better prepare students to enter college and career fields of science, technology, engineering, and mathematics (STEM; Peterson, Woessmann, Hanushek, & Lastra Anadon, 2011). The NGSS represent the latest wave of science education reform aimed at transforming science education in the United States. The new standards are the culmination of a three-year, multistep process which involved collaboration among 26 states, the National Research Council (NRC), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and Achieve, Inc. The NGSS provides a framework upon which science educators may construct a creative, flexible curriculum which will help build students' critical thinking and problem-solving skills. These skills are necessary to attain levels of STEM literacy which will guide students through the rigors encountered when studying higher-level STEM subjects and when working in STEM-related professions. The implementation of the NGSS will assist teachers in building students' interest in STEM and will better prepare students for the rigors of college and careers (Next Generation Science Standards Lead States, 2013).

A major challenge of science education of the 21st century involves the reorganizing of teaching and learning practices in science classrooms. The NGSS represent the latest iteration of science education reform in the United States aimed at transforming science teaching practices. McFarlane (2013) said modern teaching and learning practices should focus on the art of acquiring and applying scientific knowledge rather than on the notion of just knowing scientific facts. Oliveira, Wilcox, Angelis, Applebee, Amodeo, and Snyder (2013) posited best practice in middle school science teaching promotes students' abilities in inquiry through instructional strategies which are hands-on, differentiated, collaborative, and literacy-based. The new standards call for science instruction in which students are engaged in the following practices:

- asking questions and defining problems,
- developing and using models,
- planning and conducting investigations,
- analyzing and interpreting data,
- using mathematics and computational thinking,
- constructing explanations and designing solutions,
- engaging in argument from evidence,
- obtaining, evaluating, and communicating information (Next Generation Science Standards Lead States, 2013).

Teaching strategies such as these emphasize the utilitarian aspect of science. Students will develop a level of scientific literacy which is essential for navigating daily life and for responding to the many issues and challenges emerging in society requiring solutions (McFarlane, 2013).

The NGSS call for a tremendous shift from traditional methods of teacher-directed science instruction to more student-centered instruction (Pratt, 2013). The writers of the standards identified seven broad conceptual shifts as potential challenges of the NGSS: (1) Science education must show real-world interconnections in science; (2) the standards represent student outcomes; (3) science concepts should build progressively across grade levels; (4) the standards must focus on deeper understanding and application of content; (5) science and engineering must be integrated into science education; (6) the standards must prepare students for college, careers, and responsible citizenship; and (7) the standards must coordinate with the Common Core Math and Language Arts Standards (Next Generation Science Standards Lead States, 2013).

The NGSS not only address the need for change in how science is taught, but also help teachers to facilitate an integrative approach to teaching and learning which includes science, technology, engineering, and mathematics (STEM). The STEM teaching approach originated from the efforts of the Science, Technology, Engineering and Mathematics Education Coalition, which was formed in 2006. The coalition was created to increase awareness in government and other organizations about the critical role STEM education plays in assisting the United States to remain a competitive global leader (Peterson et al., 2011). Students must be prepared with the skills needed to solve problems, evaluate data and evidence, and make decisions. These skills are all learned and reinforced through science, technology, engineering, and mathematics teaching. A common belief is STEM-integrated education positively affects teacher instructional strategies, student attitudes, and academic achievement (Capraro & Han, 2014). The NGSS will serve as a guide as science teachers engage in teaching and learning within STEM.

Statement of the Problem

Organizations such as schools can experience great difficulty when faced with impending changes. The culture of uniformity in schools can make it difficult for teachers to make changes in routines and practices (Callahan & Dopico, 2016). Teachers of grades K-12 who plan and directly implement science instruction for students on a daily basis will face challenges when implementing the NGSS (Pratt, 2013). Boesdorfer and Greenhalgh (2014) attributed these challenges to teachers being wedded to past instructional practices and beliefs, and to insecure feelings about facilitating the engineering-related lessons called for by the NGSS.

Therefore, teacher preparedness at all educational levels is a concern since traditional fact- and lecture-based teaching practices are not in alignment with the mandates of the NGSS, which require more student-centered, inquiry-based learning (Haag & Megowan, 2015). Fullan and Scott (2016) noted an implementation dip is imminent at the start of any change process and the cost to the implementers (teachers of Next Generation Science) is high since there is broad unfamiliarity with the methods associated with the new institutions. Few studies have been identified which focus specifically on middle school science teachers' perceptions of the NGSS. The proposed study aims to fill this knowledge gap by providing a greater understanding of middle school science teachers' perceptions of the NGSS.

Purpose of the Study

The purpose of this dissertation study was to examine how middle school science teachers perceived the NGSS. Examining this issue allowed the researcher to identify the ideas and beliefs middle school teachers held about the implementation of the standards. Teachers' ideas and beliefs were explored relative to the following three aspects: (1) The seven conceptual shifts in K-12 science education, (2) resources and supports for NGSS implementation, and (3) barriers to NGSS implementation. Exploring the barriers to NGSS implementation helped the researcher gain information regarding the challenges middle school science teachers experienced as the standards were implemented in classrooms.

A qualitative, grounded theory study was conducted to examine middle school science teachers' perceptions of the NGSS. The participants of the study consisted of middle school science teachers who were at different levels of NGSS implementation: Initial exposure to the NGSS, deepening understanding of the NGSS, planning instruction around NGSS, and full alignment of instruction to the NGSS (California Department of Education, 2016). Sources of data for this investigation included teacher surveys, teacher interviews, and documentary sources such as lesson samples.

Research Questions

The research questions guiding this study were the following:

1. How do middle school science teachers perceive the Next Generation Science Standards?
2. What resources and support systems do teachers report as being beneficial in the implementation of the NGSS?
3. What do middle school science teachers report as being challenges or barriers to implementing the NGSS?

Research Question 1 addresses middle school science teacher perceptions of the NGSS as related to the seven conceptual shifts mentioned earlier. The seven conceptual shifts called for by the writers of the NGSS were used as a foundation for the development of the survey instrument which used to collect data. The seven conceptual shifts represent a change in the way teachers must think about teaching and learning in the science classroom (Pratt, 2013). Examining data relative to these questions helped the researcher determine how close teacher perceptions of the NGSS are to the seven conceptual shifts and teachers' level of use of NGSS practices.

Research Question 2 addresses support for NGSS implementation. The body of literature on NGSS implementation is relatively new and emerging. States across the US are in different phases regarding the implementation of the standards (Best, Dunlap, & McRel, 2014). Optimal implementation of the NGSS will require years of work and patience on the part of teachers, educational leaders, researchers, and educational policymakers (National Research

Council, 2015). Information and data gathered from this question will be informative to teachers, educational leaders, and providers of professional development by documenting successful methods of support in implementing the NGSS.

Research Question 3 addresses challenges to NGSS implementation. Shernoff, Sinha, Bressler, and Schultz (2017) described the NGSS as an intervention in science education. Interventions can be daunting and met with numerous challenges and barriers. The seven conceptual shifts alone are considered challenges because of the drastically different way in which science teachers must think about teaching and learning in science education (Pratt, 2013). Information gathered from this question will assist in giving a voice to science teachers about the actions, methods, and policies which are not helpful in promoting the implementation of the NGSS.

Significance of the Study

Studies related to teacher perceptions of educational standards are beneficial by providing valuable information to educational leaders and policymakers about how to best support standards implementation in schools. Therefore, it is imperative to examine middle school science teacher perceptions regarding the implementation of the NGSS. The findings from this study will aid teachers and education leaders in optimizing NGSS implementation efforts in middle school science settings by contributing valuable insights and knowledge about teacher perceptions of the NGSS to the field of science education. Some studies focusing on teacher perceptions and beliefs have indicated connections between teacher beliefs about pedagogical practices and the approaches used in classroom settings (Schramm-Possinger, 2016; Ireland, Watters, Brownlee, & Lupton, 2012). Examining middle school science teachers' perceptions about the NGSS will provide information regarding teacher beliefs about the standards, teachers' interpretation of the standards, and the needs of teachers when implementing the standards.

Information about teachers' perceptions of educational standards can also assist educational leaders with future professional development planning for teachers. Prior standards implementation processes have involved support in the form of institutions, workshops, and supportive materials adapted to previous standards. Quality professional development and supportive materials will be necessary in order for meaningful standards implementation processes to take place (Klieger & Yakobovitch, 2011). The findings from this study can help guide the development of resources to support the implementation of the NGSS.

The study will also aid policymakers in assessing the impact of this latest reform effort in science education. Revealing teacher perceptions of educational standards can assist policymakers when reexamining policy related to standards-based science education (Klieger & Yakobovitch, 2011). Knowledge gained from this study may be useful in empowering and guiding policymakers in making decisions about future iterations of science standards reform.

Conceptual Framework

The shift to next generation science will be demanding and will require persistence and time. The attention of school leaders and teachers will be required over many years in order to achieve the changes outlined by the NGSS (National Research Council, 2015). The NGSS Implementation Pathway Model was developed and proposed by states leading the development of the NGSS to facilitate its implementation (California Department of Education, 2014). The model identifies three broad phases in the standards implementation process: awareness, transition, and implementation. Teachers are expected to progress through four more specific stages while moving from awareness of the standards to implementation. These more specific stages include: initial exposure to NGSS, deepening understanding of NGSS, planning instruction around NGSS, and full alignment of instruction to NGSS (California Department of Education). The NGSS Implementation Pathway Model will be used to identify where teachers exist on the path toward NGSS implementation (Spiegel, Quan, & Shimajyo, 2014).

Hall, Loucks, Rutherford, and Newlove (1975) presented an extensive framework for analyzing the adoption of instructional innovations. The researchers noted the adoption of an innovation is a process rather than a decision. Therefore, there can be wide variations in the degree to which individuals utilize or implement new initiatives. This framework is referred to as the Levels of Use of the Innovation (LoU). The researchers proposed eight levels of innovation use which could be demonstrated by an individual when exposed to an innovation. These levels include the following: non-use, orientation, preparation, mechanical use, routine, refinement, integration, and renewal (Hall, Loucks, Rutherford, & Newlove, 1975). This framework was referred to in guiding the development of the open-ended survey and interview questions used in the present study. The NGSS Implementation Pathway Model and the LoU will be described in more detail in Chapter 2.

Definitions of Terms

Definitions of the terms used throughout this study are included in this section. These defined terms will assist the readers in understanding the main concepts used in the study.

Next Generation Science Standards (NGSS)

The NGSS are the newest national standards for science education in the United States. The NGSS are based on the NRC's *A Framework for K-12 Science Education* (Next Generation Science Standards Lead States, 2013).

National Science Education Standards (NSES)

The NSES were released by the National Research Council (NRC) in 1996 (National Research Council, 1996). The NSES has been a leading reform document in science education. The standards have served as a reference for state-level standards and influenced the conception of *A Framework for K-12 Science Education* (Campbell & Smith, 2013).

Science, Technology, Engineering and Mathematics Education (STEM)

STEM education refers to approaches in teaching and learning which include the integrative teaching of two or more STEM subjects or a STEM subject and one or more other subjects outside the STEM area (Stubbs & Myers, 2016).

Reform

Reform is used to describe the curricular shifts taking place as a result of the implementation of new standards. Reform, in this study, will refer to changes in science education standards which warrant changes in methods of science teaching (Bybee, 2014).

Three-dimensional Learning

Three-dimensional learning is a phenomenon in teaching and learning in which there is an integration of the core ideas of several disciplines, science and engineering practices, and crosscutting concepts (Houseal, 2016).

Performance Expectations

Performance expectations are statements within the NGSS document describing what students should be able to do (Next Generation Science Standards Lead States, 2013). Students who can perform these actions demonstrate a level of understanding consistent with what is expected by the writers of the NGSS.

Conceptual Shift

Conceptual shifts refer to changes in the ways teachers think about science teaching and learning as a result of the NGSS. Science teachers must address the educational shifts proposed by the NGSS in order to bring forth improvements in science curricula, assessments, teacher development, and student achievement (Bybee, 2014).

Learning Progressions

Learning progressions within the NGSS illustrate how student understanding of concepts should build over time. The learning progressions are summarized in a framework showing specific content which should be covered within specified grade bands from kindergarten to grade 12 (Next Generation Science Standards Lead States, 2013).

Teacher Perceptions

Teacher perceptions can refer to many factors (Moreau, 2014). Prior teacher perception studies related to STEM education referred to perceptions as thoughts, views, ideas, or images teachers have about a phenomenon in education. Teacher perceptions in this study will refer to ideas and thoughts teachers have about the NGSS and the implementation of these standards (Stubbs & Myers, 2016; Klieger & Yakobovitch, 2011).

Assumptions

The researcher assumed the middle school teachers participating in this study had some level of familiarity with the NGSS. The state of Illinois was scheduled to be in full alignment with the NGSS during the 2016-2017 school year (Illinois State Board of Education, 2016). This expectation implies science teachers should have some level of familiarity with the NGSS and should have begun to implement the standards in science instruction to some degree.

Scope and Delimitations

Delimitations define the boundaries of a research study and explain steps taken as a result of the boundaries (Simon & Goes, 2013). The first delimitation is the researcher's choice to include teachers from DuPage County, Illinois, within the research population. Limiting the population to one county ensures some degree of similarity in the teaching and learning expectations and experiences among science teachers.

This study focuses specifically on the perceptions held by middle school science teachers. Middle school science teachers in this study were identified as those teaching one of, or a combination of, sixth, seventh, and eighth grade science classes (Next Generation Science Standards Lead States, 2013). The researcher chose to focus on science teachers at this level since student interest in science, technology, engineering, and mathematics becomes more solidified at the middle school level. Students also become more curious about future STEM-related careers at the middle school level (Wyss, Heulskamp, & Siebert, 2012).

Another delimitation relates to the researcher's choice to conduct single participant interviews rather than focus group interviews. A focus group is a group of individuals selected by the researcher for participation in a discussion on the topic of research (Kellmereit, 2015). Conducting one-to-one interviews is a powerful method of gathering narrative data. Interviews allow a researcher to study participants' perceptions in great depth (Alshenqeeti, 2014).

Limitations

This study will be limited in terms of its transferability. Transferability refers to the applicability of research findings to other settings similar to those of the study (Yilmaz, 2013). Qualitative studies are designed to study a specific phenomenon within a certain population (Leung, 2015). Leung noted the ability to the transfer findings of qualitative studies can be controlled pragmatically by employing methods of systematic sampling, triangulation, constant comparison, and proper documentation. The conclusions from this study are limited to middle school science teachers in DuPage County, Illinois. The findings could be extended with care by educators whose circumstances are well matched to those of this study according to Leung's guidelines.

The concept of dependability refers to a study's consistency over time and across various methods imposed by different researchers (Yilmaz, 2013). A study's level of dependability rests on the researcher's ability to fully control and carry out the research agenda. The researcher must ensure alignment between the research questions and methods of data collection and analysis. The researcher checked for parallelism across three data sources in an effort to increase the study's dependability.

This study also utilized closed-ended surveys to ascertain teacher perceptions of the NGSS. Close-ended questions provide the respondent with a predetermined list of answer choices. Surveys of this type can be limiting since respondents can be forced into certain response categories (Simon & Goes, 2013). This can affect the range of responses a respondent is likely to give in the absence of preset response choices. The closed-ended questions will elicit answers on a five-point Likert-type scale. This kind of survey is commonly used to collect data on participants' behaviors and attitudes (Edmondson, Edwards, & Boyer, 2012).

Chapter Summary

The Next Generation Science Standards (NGSS) represent the latest wave of science education reform aimed at transforming science education in the United States (Next Generation Science Standards Lead States, 2013). Teachers of grades K-12 who plan and directly implement science instruction for students on a daily basis may face challenges when implementing the NGSS (Pratt, 2014). The proposed qualitative research study will examine perceptions of the NGSS held by middle school science teachers. Studies related to teacher perceptions of educational standards can provide valuable information to educational leaders and policymakers about how to best support standards implementation in schools. The next chapter will provide a review of literature relevant to this study.

Chapter 2: Literature Review

Conversations are taking place about the importance and relevance of STEM (Science, Technology, Engineering, and Mathematics) education in today's society. Nations around the world are discussing how to incorporate and improve STEM education in schools (DeBoer, 2011). The International Council of Associations for Science Education (ICASE) has called upon researchers, teachers, and policymakers involved in STEM education to place greater emphasis on better preparing students for STEM fields, as not doing so could have a drastic impact on the global economy (Kennedy & Odell, 2014). Transformations are being made in the field of science education in the United States in an effort to solve this problem. The Next Generation Science Standards (NGSS) represent the latest wave of reform in science education. The purpose of the standards is to improve students' abilities to engage in the analytical and problem-solving processes of science. The NGSS were introduced in 2013 and are expected to drastically change the landscape of teaching and learning in science in the years to come (Next Generation Science Standards Lead States, 2013). Teachers of grades K-12 who plan and directly implement science instruction for students on a daily basis may face challenges when implementing the NGSS (Pratt, 2014).

The purpose of this dissertation study was to examine how middle school science teachers perceive the NGSS and to explore teacher experiences with implementation. Examining how teachers perceive the NGSS will allow identification of the ideas and beliefs teachers hold with respect to the implementation of the NGSS. Savasci and Berlin (2012) explained teacher beliefs about policies in education can influence how such policies are implemented. Therefore, it is important to examine science teachers' perceptions of the NGSS when addressing its implementation. This study will contribute valuable insights and knowledge about teacher perceptions of the NGSS to the field of science education research. The knowledge gained from this study may be useful for informing educational leaders about preparing middle school science teachers to facilitate classrooms with NGSS-based curricula.

This review of literature will begin with the establishment of the conceptual framework in which the study is grounded. Research studies related to the conceptual framework and teacher perceptions will be reviewed first. The following sections will provide an overview of science education reform in recent decades and the history and development of the NGSS. Additional literature will be reviewed in the latter sections of this chapter related to the incorporation of technology and engineering into classrooms as part of the NGSS, NGSS implementation, and critiques of the NGSS.

Literature Search Strategy

A literature review serves to assist a researcher in becoming familiar with an emerging domain and provides a theoretical framework for a study (Paré, Trudel, Jaana, & Kitsiou, 2015). A thorough literature review is essential for advancement in the knowledge and understanding of a particular topic and to understand the breadth of the existing information for a particular field (Linn, Gerard, Matuk, & McElhaney, 2016). The information for this literature review was gathered using databases such as ERIC and Google Scholar. Relevant search terms and phrases used in the search process included combinations of the following terms: *science education*, *educational standards*, *NGSS*, *middle school science*, and *teacher perceptions*.

Conceptual Framework for Implementation of NGSS

The classroom teacher plays a critical role in the implementation of educational reforms. Teachers' beliefs, cognition, and context all play a part in the ability to make sense of policies related to education. Classroom teachers must be able to understand the instructional expectations dictated by policy and envision how standards will be applied in the classroom. Teachers must also be consistent in the use of best instructional practices in order to maintain educational reforms and improve student achievement (Hall, Dirksen, & George, 2013).

The implementation of the NGSS represents a change from traditional methods of science teaching. This change will be demanding and will require persistence and time to fully implement. The attention of school leaders and teachers will be required for an extended period of time in order to achieve the outcomes expected by the NGSS (National Research Council, 2015). Change can be difficult to embrace. The NGSS Implementation Pathway Model was developed and proposed by the U. S. states leading the development of the NGSS. This model provides a guide for the phasing-in of the NGSS (California Department of Education, 2014).

The NGSS Implementation Pathway Model presents three broad phases in the standards implementation process: *awareness*, *transition*, and *implementation*. Teachers are expected to progress through four more specific stages while miving from awareness of the standards to implementation of the standards. The more specific stages include: (1) initial exposure to NGSS, (2) stage deepening understanding of NGSS, (3) planning instruction around NGSS, and (4) full alignment of instruction to NGSS (California Department of Education, 2014).

The awareness phase of the NGSS Implementation Pathway Model involves teachers' initial exposure to the NGSS (Stage 1). Teachers begin to learn about the standards and understand the critical components of NGSS such as the three-dimensional learning and performance expectations (Spiegel, et al., 2014). Each component has important implications for the conceptual shifts teachers must grasp in order to successfully implement 'next generation science' (Reiser, 2013). Teachers also begin to develop a deeper understanding of the NGSS during this phase by engaging in research and professional development, Stage 2 (Spiegel, et al., 2014). Reiser (2013) noted professional development for teachers will be essential in supporting 'next generation science.' Teachers will need extensive support in learning about the standards, facilitating activities which are standards-based, and teaching with the aims of the NGSS in mind (Reiser, 2013).

The second broad phase of the model is the transition phase. Teachers continue to develop a deeper understanding of the NGSS during this phase through research and professional development. The transition phase also encompasses the planning of instruction around the NGSS (Stage 3). This stage is evident when teachers begin planning units and lessons aligned to the standards. Teachers may experiment with the standards by taking an existing activity or unit and translating it into an NGSS-based lesson (Spiegel, et al., 2014). Teachers should structure lessons so classwork is guided by questions which come from the students rather than follow a prearranged list of topics (Reiser, 2013).

The final broad phase is implementation. The implementation phase involves teachers transitioning from planning instruction around the NGSS to full alignment with it. Full alignment to the standards (Stage 4) is evident when teachers design and plan all instruction and formative and summative assessments around the NGSS (Spiegel, et al., 2014).

A similar, more extensive framework was presented by Hall, Loucks, Rutherford, and Newlove (1975) in the 1970s, called the Concerns-Based Adoption Model (CBAM). The CBAM consisted of two dimensions: The Stages of Concern about the Innovator (SoC) and the Levels of Use of the Innovation (LoU). The SoC describes the concerns of an individual during the implementation of an innovation. The LoU describes how an individual's performance changes as familiarity with the innovation grows. The CBAM places the teacher as the point of focus with respect to school improvement. This model has been used in the past to conceptualize the needs and uses of change programs (Loucks & Hall, 1979).

This framework applies to the present qualitative study, as the NGSS can be seen as an innovation which is being used and implemented by teachers in science classrooms. Eight levels of innovation use were described in the LoU which could be demonstrated by an individual exposed to an innovation. These levels include the following: non-use, orientation, preparation, mechanical use, routine, refinement, integration, and renewal (Hall, Loucks, Rutherford, & Newlove, 1975). The LoU rubric illustrates a range of behaviors as individuals acquire new skills in the use of an innovation. These behaviors are apparent across three categories: knowledge, the acquisition of information, and sharing. The following are descriptions of each level:

1. Non-use (Level 0): An individual has little or no knowledge of the innovation and makes no effort to learn about it.
2. Orientation (Level 1): An individual gains knowledge about the innovation and investigates the value and demands associated with using it.
3. Preparation (Level 2) – An individual prepares to use the innovation for the first time.
4. Mechanical use (Level 3) – An individual engages in a step-by-step process which assists in the day-to-day use of the innovation. Adjustments are made to meet the needs of the user rather than the client.
5. Routine (Level 4 A) – An individual becomes comfortable using the innovation. Few other changes are being made to the innovation. The user incorporates very little thought or effort into the improvement of the innovation.

6. Refinement (Level 4 B) – The use of the innovation is differentiated to meet the needs of different clients. The user considers the short- and long-term effects on clients.
7. Integration (Level 5) – The user seeks to have a collective effect on clients by utilizing the innovation along with activities generated through collaborations with colleagues.
8. Renewal (Level 6) – The user assesses the use of the innovation and seeks to modify it to increase its impact on clients. The individual also explores new developments regarding the innovation and sets new goals for themselves and clients (Hall, et al., 1975).

Research Literature Review

A review of current literature is provided. Topics include: innovations in education, teacher perceptions, science education reform, science literacy, NGSS development, including the ideas, concepts and practices of science education.

Innovations in Education

Thornton, West, & Alquist (1999) conducted a study which sought to analyze and evaluate the extent to which teachers used a new mathematics curriculum during the first and second years of its implementation. The Department of Defense Dependent School District of Hessen, Germany began implementing the new mathematics curriculum in 1989. The curriculum was intended to reflect the intent of the *Curriculum and Evaluation Standards for School Mathematics*, which was published in 1989 by the National Council of Teachers of Mathematics (NCTM). The researchers identified 140 eligible elementary and middle school educators. Interviews were conducted with 102 educators during the first year and 106 educators during the second year. The researchers established the LoU for each teacher who was interviewed during the first and second years.

Thornton et al (1999) discovered 59% of teachers existed at Level 3 during the first year of the study. Level 3 represents *mechanical use*. Teachers operating at this level were not focused on student results or outcomes. Teachers were also not engaged in endeavors involving long-range planning. The overall impression was teachers were operating at a level at which the logistics of curriculum implementation was relatively easy for themselves. The researchers reported 32% of teachers were still operating at the *mechanical* LoU by the end of the second year of the study. The researchers attributed this sustained *mechanical* LoU to changes in grade level assignments and new entry into the mathematics program.

Few teachers in this study moved into higher LoUs such as Level 4B (refinement), Level 5 (integration), and Level 6 (refocusing). Thornton et al (1999) contributed the success of teachers who moved into higher LoUs to several things: The teachers may have used similar curricular programs in the past; some teachers may have volunteered to pilot the new math curriculum before the study began; some teachers may have already been familiar with the math content and concepts; teachers were risk-takers who received administrative support to engage in curricular experimentation and, as a result, modifications in teaching practices were made in ways which increased student learning.

Cardoza & Tunks (2014) conducted a case study evaluating a private school's teacher's LoU of the Bring Your Own Technology initiative (BYOT). This initiative was enacted in order to increase students' skills and the level of technology use in the classroom. The researchers collected data from 12 teacher participants through questionnaires, interviews, and observations. Teacher's concerns toward the adoption of the BYOT program were assessed using three components of the CBAM: The Stages of Concern Questionnaire (SoCQ), Levels of Use (LoU), and the Innovation Configuration Map (IC Map).

The 12 participants took the SoCQ at three different intervals during the school semester. The questionnaire guided the researchers in assessing teachers concerns about BYOT. Six participating teachers were invited to take part in a series of three one-on-one interviews. The interviews assisted researchers in collecting information regarding teachers' backgrounds and professional and personal experiences, experiences with BYOT, and factors influencing teachers' concerns and behaviors toward the implementation of BYOT. The IC Map listed the parts of the innovation adopted, and illustrated methods for implementation (Cardoza & Tunks, 2014).

Cardoza & Tunks (2014) discovered five of the six interviewed teachers had concerns related to themselves. Teachers with concerns related to themselves indicated a need to learn more about the BYOT initiative, such as the time required for preparation, implementation timelines, and administrator expectations. Many teachers were concerned about the ability to implement BYOT as expected by school leaders. Four of the six teachers were rated to be at Level 3 of the LoU—*mechanical use*. Teachers who operated at this level were focused on the daily use of technology and did not give much thought to how students were affected. The two remaining teachers were rated at Level 4—*routine use*. Teachers at this level were comfortable with the implementation of BYOT, but had no plans to improve implementation efforts. The researchers further discovered teachers who demonstrated *mechanical use* were in the first or second year of teaching, while teachers who demonstrated *routine use* had five or more years of teaching experience. The IC Map results indicated the majority of teachers implemented BYOT at a level similar to what was envisioned by school leaders. Observations typical of this level included student work being devoid of real-world connections, teacher-directed learning, and low promotion of student creativity. None of the teachers achieved the ideal level of implementation on the IC Map. This level would involve observations such as the promotion of innovative thinking among students, real-world problem explorations, student self-reflection, student collaboration, and varied technology use.

Nadelson and Seifert (2016) conducted an educational innovation study within a week-long professional development program in STEM. It sought to examine the characteristics and behaviors associated with teachers' decisions to adopt and implement an educational innovation. It also sought to determine whether the professional development program impacted any variables associated with a teacher's motivations to embrace and adopt an educational innovation. The study reported the teachers' professional behaviors which were associated with the level of comfort in teaching STEM, and created a model related to teachers' propensity to engage with and adopt innovations.

Nadelson and Seifert (2016) concluded knowledge seeking, embracing change, having opportunities to explore, and acting with a sense of responsibility were all behaviors which were significant predictors of teachers' propensity to embrace and adopt an educational innovation. The researchers further concluded reinforcing and supporting the teacher behaviors associated with the adoption of educational innovations would create a culture in which increased attention and consideration would be given to the connection between teacher behaviors and the implementation of large-scale educational innovations.

Teacher Perceptions

Several studies have examined perceptions of science education standards. Klieger and Yakobovitch (2011) conducted a teacher perception study involving the National Science Education Standards (NSES). The researchers sought to uncover teacher perceptions of the standards' effectiveness on teaching and learning, differences in implementation by grade level, and the ease of implementation. Some 97% of teacher participants viewed the science standards as effective for teaching and learning, and cited several reasons for these views. The standards increased the quality of learning, maintained curricular and instructional focus, and enabled teachers to make connections between science concepts and between disciplines. Teachers also reported the use of the standards assisted in making connections between science concepts and everyday life (Klieger & Yakobovitch, 2011). Differences were noted in the extent of implementation of the science standards at different grade levels. Different degrees of difficulty in the implementation of the science standards was also perceived (Klieger & Yakobovitch, 2011).

Smith and Nadelson (2017) sought to determine the level of alignment between the teaching practices of teachers in Grades 3-5 and the NGSS teaching practices. The broad goal of the research was to determine the extent to which elementary school teachers incorporated NGSS teaching practices into the science curriculum. The researchers discovered teachers had already been implementing some NGSS practices but could not formally articulate what were. The NGSS practices 1, 3, and 8 were the ones elementary teachers most commonly incorporated. These are: asking questions (1), planning and carrying out investigations (3), and obtaining, evaluating, and communicating information (8). The NGSS practices teachers were less likely to incorporate were practices 2, 4, 5, 6, and 7: developing and using (2), analyzing and interpreting data (4), using math and computational thinking (5), constructing explanations (6), engaging in argument (7). The researchers also discovered school culture, professional development, and access to instructional resources were among what teachers perceived to be essential for the successful implementation of NGSS practices (Smith & Nadelson, 2017).

Stubbs and Myers (2016) investigated perceptions of STEM and its integration in an agriculture curriculum in three high school agriculture teachers. Teachers generally perceived STEM as beneficial and positive for students but had concerns as to whether too much STEM integration would lessen student interest. The results indicated the history of teachers' educational experiences influenced current perceptions of STEM integration. Teachers incorporated STEM into the curriculum by drawing upon resources such as personal knowledge, internet resources, and professional development materials. The study also showed STEM-related professional development and training encouraged teachers to integrate more STEM into the curriculum. All teachers who were part of the study perceived STEM integration improved the academic achievement and engagement of students. The integration of STEM in agriculture was perceived to be supportive of curricular content in other disciplines. The researchers concluded teacher perceptions affected the nature and scope of STEM integration (Stubbs & Myers, 2016).

Studies focusing on teacher perceptions of educational standards have also been conducted in non-science areas. Burks, Beziat, Danley, Davis, Lowery, and Lucas (2015) investigated teacher perceptions of the Common Core State Standards (CCSS). The study's focus was on examining teachers' level of comfort in CCSS implementation and whether teachers felt adequate training was received beforehand. Some 57% of surveyed teachers expressed high levels of comfort regarding the preparedness to implement the CCSS. Fifty-five percent reported adequate training was not received. Some 47% of teachers reported participation in at least three professional development training sessions conducted by a fellow staff member at the same school (Burks, Beziat, Danley, Davis, Lowery, & Lucas, 2015).

Sen and Sari (2017) investigated preservice teacher beliefs about teaching science and perceptions of the nature of science. The researchers sought to uncover the relationship between preservice teachers' perceptions of the nature of science and personal beliefs about science education. Two teacher belief categories were identified: traditional beliefs and reform- based beliefs. Traditional beliefs refer to ideas rooted in teaching methods which are less student-centered. Reform-based beliefs are those stemming from more student-centered teaching practices involving active learning. The study concluded preservice teachers possessing more traditional beliefs were likely to have a minimal understanding of the nature of science, while those who expressed reform-based beliefs were more likely to have a realistic perception and understanding of the nature of science (Sen & Sari, 2017).

Sarieddine and BouJaoude (2014) conducted a qualitative study to examine the relationship between teacher conceptions of the nature of science and classroom practices. Seven 10th grade biology teachers participated in the study and completed surveys, interviews, and observations. Sarieddine and BouJaoude (2014) made three assertions based on this study: (1) The study participants held inaccurate and inconsistent views of the nature of science. (2) Aspects of the nature of science were not taught in the classroom. (3) The teacher participants emphasized traditional teaching methods such as rote memorization, lecturing with low student engagement, and providing few problem-solving opportunities. The researchers emphasized the incongruence between the aforementioned practices and the nature of science. Individuals who understand the nature of science are more informed about science and are more empowered to make decisions about issues related to science. The researchers further concluded teachers' knowledge and understanding of the nature of science is explicitly translated into the classroom through curricular practices (Sarieddine & BouJaoude, 2014).

Studies are emerging from which researchers are learning more about the impact of the NGSS in various educational settings. Shernoff, et al (2017) investigated the impact of an NGSS teacher professional development model on teachers' utilization of NGSS standards. The researchers' goal was to create, implement, and assess a model of professional development which addressed the major conceptual shifts occurring in science education. This model utilized problem-based learning and constructivism as the primary educational approaches through which next generation science was delivered. The researchers found five out of the six teacher participants indicated significant shifts in pedagogy and the curriculum after participating in the model of NGSS professional development. Lack of planning, instructional time, knowledge, and the skills required to teach certain aspects of Next Generation Science were among the common implementation challenges reported by teacher participants. Five out of the six participants reported a transition within themselves—from a novice to becoming an accomplished novice—by participating in the NGSS professional development model. The level of *accomplished novice* referred to teachers who possessed the ability to navigate the standards sufficiently to begin planning lessons. The level of understanding and application of the NGSS varied widely as indicated through the analysis of teacher lesson plans. Information discovered through the analysis of teacher lesson plans was not consistent with teacher self-perceptions (Shernoff, et al., 2017). The inconsistencies discovered between what was represented in the lesson plans and teacher self-perceptions implies further studies are needed which focus on teachers' perceptions of the NGSS and its implementation.

Science Education Reform

Science is not a static discipline. There are constant changes which have implications for what becomes current scientific knowledge. Educators must be flexible and adapt to science to reflect its changing nature in the classroom environment (McFarlane, 2013). Continued learning is essential for science teachers. Advances in science knowledge oblige teachers to minimize methods of teaching which no longer serve 21st century learners (Bybee, 2014b). Innovative classroom practices such as problem-solving, modeling, and engineering design require changes in the conceptualization and processes of teaching and learning (Callahan & Dopico, 2016). Future progress in the sciences is dependent upon the recruitment of individuals who possess the ability to think critically, solve problems, and demonstrate innovation (McFarlane, 2013). Students who have exposure and access to science programs which cultivate such skills are more likely to acquire an increased level of scientific literacy.

Science Literacy

Calls for literacy education were made in the early 1900s by William S. Gray. Gray was instrumental in the education reform movement by highlighting the importance of reading and writing in daily life. Gray concluded reading and writing are essential to the well-being of individuals and advocated for functional literacy. Functional literacy refers to the level of knowledge and skills needed for individuals to engage effectively within a culture or group (Gray & Staiger, 1969). Definitions of scientific literacy have surfaced over the last several decades in an effort to explain the extent to which students should know science. Crowell and Schunn (2016) described scientific literacy as the baseline level of knowledge needed to understand science. Trauth-Nare (2016) contended scientific literacy extends beyond the mastery of scientific knowledge and includes abilities such as critical thinking and analysis, and the application of knowledge to socially-relevant situations. Krajcik, Codere, Dahsah, Bayer, and Mun (2014) said students who are scientifically literate possess the ability to make well-informed decisions as citizens, are better prepared for college studies and careers in the sciences, are able to compete in the global economy, and can understand and appreciate science in day-to-day life. The NGSS will support the development of scientific literacy by minimizing the separation of content and practice in the science classroom (Passmore, 2015).

Crowell and Schunn (2016) concluded the amount of science education one receives does not determine one's scientific literacy. Scientific literacy is a result of one's exposure to, and involvement in, experiences in which scientific knowledge and practices are used together to solve problems. It is the *quality* of one's science education which affects one's scientific literacy. McFarlane (2013) declared educators must help students embrace the responsibility of developing skills in scientific literacy by creating autonomous learning experiences to supplement formal learning in the classroom. Science teachers must guide students along educational pathways which will help develop the skills necessary to become critical consumers of science (Trauth-Nare, 2016). Students become critical consumers of science by learning to analyze scientific information using critical thinking skills. Students must learn to become selective and make informed decisions based on critical analysis.

Trauth-Nare (2016) posited one of the goals of science education is to provide equal and inclusive opportunities which allow students to engage in the processes of science. The aforementioned opportunities should include processes such as planning and conducting investigations, analyzing data, using models, engaging in computational thinking, constructing explanations, and engaging in scientific argumentation. Trauth-Nare (2016) noted the most important goal of science education is for students to have the opportunity to participate in science which has personal relevance and meaning. This opportunity allows students to experience the world in new ways, transfer what has been learned to the world outside of the classroom, and develop a sustained interest in science.

Science Education Reform – Post-World War II

Recommendations for reform in science education have greatly influenced science curriculum development and instruction over the past several decades. Therefore, it is necessary to review how these recommendations have helped shape science education today (Bratten & Windschitl, 2011). Science education in America has experienced numerous shifts in efforts to improve student performance, appreciation of the discipline, and levels of scientific literacy. The shifts in science education have been largely in response to changes in science, technology, the learning sciences, and educational policy (Linn et al., 2016).

During the Post-war era, there was a focus on the civic responsibility of citizens. This focus was a primary goal for K-12 education. The American education system needed major repairs in the years after World War II. Many efforts to improve education were initiated before the war were put on hold as the country fought (Wissehr, Concannon, & Barrow, 2011). American education was affected by the war in several ways. There was an increased need for the production of supplies and food and the training of individuals who would fight. Therefore many vocational and applied education programs became strengthened while responding to the needs of the time. A large number of people were deficient in basic literacy, as screenings began for those who would potentially participate in the war. There was a decline in the number of experienced workers as many talented individuals left positions in science, technology, and education to join the war effort. World War II gave rise to the increased use of science and technology as America competed with other industrialized nations like the Soviet Union (Wissehr et al., 2011). Research in numerous areas of science was accelerated because of the war. Technology, nuclear energy, rocketry, ecology, and medicine were all areas of intense focus and development (Fuller, 2013).

Science education took on two roles. One was to educate and replenish the science talent extracted from existing professions and reassigned to the war effort. The second role was to provide all students with an education in the sciences (Linn et al., 2016). A report called *Science: The Endless Frontier*, published by the National Science Foundation (NSF) in 1945, advocated the importance of science in society and suggested future American science talent would depend on the quality of science education programs (Jones & Jaffe, 2015). This report called for the establishment of the *National Science Foundation Act* in 1950 (Jones & Jaffe). The NSF aided in several reform efforts and placed emphasis on specialized education so as to increase the number of individuals entering science professions (Wissehr et al., 2011). The second role of science education was to provide all students with a general education in science. A progressive movement began in science education as more and more people became interested in this function of the science curriculum. This progressive movement was characterized by a focus on the social relevance of science education. The organization of non-specialized science courses, such as life skills-oriented science courses, accommodated students who were not aspiring to be scientists. Instead, the courses helped all students face and address scientific dilemmas (Linn et al., 2016). A publication called *Education for All American Youth*, published in 1944, emphasized the development of personal and social goals by supporting a progressive general education in all disciplines (Bybee, 2011).

There was still great concern about the way science courses were organized and facilitated. Science was taught in such a way which emphasized only the structure and content of the discipline for many years. The focus was more on the learning of discrete facts as opposed to the application of knowledge (Pruitt, 2014). There were later calls for science teaching which was more practical and applicable to one’s life (Feinstein, 2011). Making science functional in the lives of individuals became a primary goal of science education in the years after World War II.

The launching of the Russian satellite *Sputnik* was what most inspired the direction of science education in the 1950s (Wissehr et al., 2011). This foreign achievement sparked much controversy for Americans. The accomplishment was seen as a possible threat to America's reigning position as leader among nations in defense, science, and technology. Efforts to reform science education had already begun years prior to the launching of the satellite. This historical event caused scientists and math and science educators to think seriously about revising the reform efforts of the time (Linn et al., 2016). A nationally prominent science education reformer, Paul DeHart Hurd, officially adopted the term "scientific literacy" in 1958 and pushed for science education efforts which would emphasize the importance of science and its practicality to our way of life (Feinstein, 2011).

Science education reform efforts continued into the decade of the 1970s which was not a decade of endearment for science education. People began to question previously held values and ideas related to social and economic growth and progress. Many previously NSF-funded professional development programs ceased. Complex science topics were introduced at earlier grade levels, and much science instruction was too difficult for most students. Teachers were criticized for not successfully covering or teaching material in textbooks (Linn et al., 2016). Science educators developed a negative view of science textbooks during this time as many believed text resouces were disconnected from experience. There were few advances in reading during the 1970s and 1980s as a result of the negative perceptions of textbook resources (Yore & Tippett, 2014).

One of the most notable shifts in science education occurred just after the publication of a report in 1983 by the National Commission on Excellence in Education on the status of American education, called *A Nation at Risk* (Mehta, 2015). *A Nation at Risk* invoked a crisis in American education. The report was followed by criticisms of intellectual deficiencies among American students. Two major claims arose in response to the report. The first was American schools were not performing well. Indicators of the poor state of American education included low literacy levels, low performance compared to other nations, and a decline in SAT scores from 1963 to 1980 (U.S. Department of Education, 1983). The second was the deficiencies in the American education system were having negative effects on the economy. Reformers felt education in America needed to be more rigorous and more intellectually challenging (Mehta, 2015). The publication of *A Nation at Risk* spurred reform in the areas of standards-based assessment and accountability, school finance, teacher professional development, and school choice. Each area of reform was critical, but increased attention and focus on standards-based assessment and accountability was what ignited an important paradigm shift—the standards-based reform movement.

The Standards-based Reform Movement

The standards-based reform movement was born in the late 1980s to battle the claims prompted by *A Nation at Risk.* The standards-based reform movement operated by way of four components: (1) a framework which detailed what students should know and when should know it; (2) textbooks or media were used to convey accountable knowledge; (3) tools of assessment which showed how well students had gained knowledge; and (4) a system of rewards and penalties (Murnane & Levy, 2001). Desimone (2013) explained the vision of standards-based reform was to improve teaching and learning. Improvements in teaching and learning were to be accomplished through the creation of high-quality content standards which provided meaningful and universal learning goals, the creation of student assessments aligned to the standards, support systems which helped build teachers' ability to successfully implement standards, and incorporation of accountability measures to motivate educator compliance. The standards movement has been the most widely accepted education reform effort since 1983.

President George Bush held an education summit with the nation's governors in 1989. The leaders established six broad goals for education to be reached by the year 2000 (Pense, Freeburg, & Clemons, 2015). These goals were published by the National Education Goals Panel (1991) and included the following: (1) All students should start school ready to learn. (2) The high school graduation rate will increase by 80%. (3) All students will gain competence in challenging subject matter. (4) Teachers will be equipped with the knowledge and skills needed to facilitate classrooms. (5) Students in the US will be number one in the world in mathematics and science achievement. This goal arose from the below-average state of student performance in math and science. (6) Every American adult will be literate.

Educational organizations at the national and state levels have begun to more seriously consider the notion of standards-based education. The National Council of Teachers of Mathematics (NCTM) was one of the first organizations to publish a set of standards, the *Curriculum and Assessment Standards for School Mathematics*, in 1989. These standards represented the organization's view of what students in schools across the United States should know. These standards were used by numerous states as a model for revising mathematics curricula and assessments. This publication also prompted other discipline-based organizations to consider and develop similar publications which prescribed the essential knowledge and skills to be acquired by students (Rothman, 2012). The standards created by the NCTM were written with the intent to ensure the quality of education, to specify educational goals, and encourage change in the education system (Carr, Bennett, & Strobel, 2012).

The National Education Goals Panel and the National Council on Education Standards and Testing were established in 1990. These groups were challenged with the task of defining the subject matter, types of assessments and standards of performance for K-12 students. The efforts of these groups led to the establishment of national standards in numerous subject areas. The movement became more visible at the state level after 1990 as states began to formalize common educational standards for students (Pense et al., 2015).

Calls for educational standards continued as surveys revealed the American public strongly supported standards in education which were clear and specific. Students also indicated higher educational standards would increase classroom learning (Pense et al., 2015). Standards helped to increase the transparency of educational goals and made clear the expectations of students and teachers (Haag & Megowan, 2015).

After reviewing the state of science education in the mid-1980s, discussions between scientists and science education professionals sparked national-level reform efforts which were geared toward improving the way science was taught and learned in schools. The national standards reform movement gave rise to several national-level science education reform proposals emerging from the following organizations: the American Association for the Advancement of Science (AAAS), the National Science Teachers Association (NSTA), and the National Research Council (NRC; Linn et al., 2016).

The purpose of the AAAS was to define scientific literacy and outline the content and processes necessary for its achievement. The AAAS launched Project 2061 in 1985 after the passing of Halley's Comet. The project name was based on the notion of students starting school in 1985 would witness the return of Halley's Comet. A driving force behind Project 2061 revolved around questions about what scientific and technological advancements would occur in the lifetimes of the current generation of students, and whether or not these students would be prepared to function as a well-informed citizenry in such a context (AAAS, 2013). Project 2061 consisted of panels of expert scientists, mathematicians, and technologists who made suggestions for science education reform. Project 2061 was an extensive initiative of the AAAS aimed at improving literacy in the areas of science, mathematics, and technology. The recommendations from Project 2061 were compiled and revealed in a 1990 publication called *Science for All Americans* (Science For All Americans, 1990; American Association for the advancement of Science, 2017).

The NSTA sponsored a project called Scope, Sequence and Coordination of Secondary School Science (SS&C) in 1992. The purpose of the project was to increase scientific literacy by changing the way in which science was taught and by reorganizing science education. This reorganization included the incorporation of hands-on experiences in science, appropriate sequencing of science concepts and levels of abstraction over time, and the consideration of students' preconceptions in science. This project voiced the interests of science teachers and administrators as well as science education faculty members (Ault, 2015).

The AAAS produced the *Benchmarks for Scientific Literacy* in 1993, which emerged from Project 2061. The minimum knowledge specific grade levels should acquire was prescribed through this publication. *Benchmarks* gives statements describing the knowledge all students should have and the skills students should be able to perform in science, mathematics, and technology. Grades 2, 5, 8, and 12 were identified as checkpoints at which the development of the required knowledge and skills, as outlined in SFAA (AAAS, 2013), should be assessed.

The NRC was established in 1994 with a purpose to create a national set of standards for science education which would encourage science educators to think of science, not as just a rote learning process involving observation, inference and hypothesizing, but as a discipline which incorporates these skills with scientific knowledge, reasoning, and critical thinking into a comprehensive understanding of science (Campbell & Smith, 2013). These standards were published as the *National Science Education Standards* (NSES). The NSES provided a vision of a scientifically literate society. The document outlined what students needed to know, understand, and do to be considered scientifically literate at each grade level. The NSES aimed to create an educational setting in which every student could demonstrate high levels of performance. The NSES promoted hands-on science and identified content each student should know by the end of each grade level. Teachers were also empowered to make important decisions to foster effective learning. This vision also stressed the importance of educational programs which encouraged, nurtured, and supported student achievement (Campbell & Smith, 2013).

The NRC published *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* in 2012. The Framework was developed by the Committee on a Conceptual Framework for New K-12 Science Education Standards (National Research Council, 2012). This document expressed broad expectations for students in science and was meant to guide the development of new standards which would catapult science curricula, instruction, assessment, and teacher professional development to new levels (Bybee, 2013). The goal of the Framework was to ensure by the completion of grade 12, the following would occur: (1) students would possess adequate functional knowledge of science and engineering, (2) students would be informed consumers of science and technology-related information, (3) students' knowledge of science would increase beyond the K-12 school setting, and (4) students would possess the skills to enter science, technology and engineering-related careers (National Research Council, 2012).

NGSS Development

The Committee on a Conceptual Framework for new K-12 Science Education Standards recommended K-12 science education be organized around three dimensions: science and engineering practices, crosscutting concepts which connect the fields of science, and core ideas from the disciplines of physical science, life science, earth science and space science. The committee noted all three dimensions should be integrated into standards, curricula, instruction, and assessment in order for meaningful science learning to take place. The Framework also stressed the importance of providing many opportunities for all students to enhance and revise scientific knowledge and understanding with science and engineering practices (National Research Council, 2012).

The completion of the Framework paved the way for the development of science standards for today's modern classrooms. This new set of standards, called the *Next Generation Science Standards* (NGSS), were released in April 2013. The NGSS represent a revision of the 1996 *National Science Education Standards* (Campbell & Smith, 2013). The new standards are also based on the *Framework for K-12 Science Education* (Next Generation Science Standards Lead States, 2013). State boards of education have been examining the new standards based on merits and the individual needs of each state. Eighteen states and the District of Columbia have adopted the new standards as of 2017 (National Association of State Boards of Education, 2017).

Twenty-six states, including Illinois, became lead state partners in the development of the standards. The lead states provided feedback and guidance to a team of 40 people writing the standards. The lead state partners were composed of various educational organizations within each of the 26 participating states. The lead states were committed to providing guidance by meeting with the writers of the standards to provide direction and facilitate consensus regarding the aboption and implementation of the standards (Next Generation Science Standards Lead States, 2013). The team of writers was composed of educators and administrators from the fields of K-12 education, higher education, engineering, science, and research. The first step in the development of the standards involved achieving a common understanding of science and engineering practices. The second step involved the identification and development of crosscutting concepts and disciplinary core ideas (Pruitt, 2014).

Three-dimensional Learning

The phrase *three-dimensional learning* is used when referring to the NGSS, as these standards represent an integration of three learning paradigms: *disciplinary core ideas*, *cross-cutting concepts*, and *science and engineering practices*. The three dimensions of science learning were identified in the *Framework for K-12 Science Education* (National Research Council, 2012). Krajcik (2015) concluded the transition to three-dimensional learning will be challenging for many science teachers since there are few resources to offer guidance at this time. The notion of three-dimensional learning was proposed to provide science educators with a practical method of guiding students in the development of critical science skills and content knowledge. Krajicik (2015) insisted teaching in this way will help students in three ways. Students will develop deeper understanding and be able to apply knowledge to new and more challenging situations. Students will develop skills such as the ability to solve problems, critical thinking, communication, and the ability to self-manage. It is important for science educators to conceptualize three-dimensional learning as the NGSS advocates there should be little separation between the teaching of science content and science practices (Passmore, 2015).

Disciplinary core ideas. *Disciplinary core ideas* represent a small set of core ideas drawn from four major science domains: physical sciences, life sciences, earth and space sciences, and engineering and technology (Houseal, 2016). The ideas are based on four guidelines: (1) core ideas must have broad importance across several science disciplines; (2) the idead must be instrumental in helping to understand more complex ideas or problems in science; (3) core ideas must have connections to the interests, experiences or societal or personal concerns of students; and (4) the ideas must be learnable across grade levels with increasing levels of sophistication (Next Generation Science Standards Lead States, 2013).

Crosscutting concepts. *Crosscutting concepts* include the overarching ideas around which broader connections and understanding can occur (Houseal, 2016). Crosscutting concepts serve as connectors between disciplinary boundaries. The cross-cutting concepts include ideas such as (1) patterns, (2) cause and effect, (3) scale, proportion and quantity, (4) systems and system models, (5) energy and matter, (6) structure and function, and (7) stability and change. These concepts are not specific to any one discipline of science, but "cut" across all disciplines (Next Generation Science Standards Lead States, 2013). Scientific ways of thinking are engendered across all of these disciplines via the cross-cutting concepts.

Science and engineering practices. The *Science and Engineering Practices* are those which represent the process of physically engaging in science. Science and engineering practices are the skills and actions scientists employ when investigating the world around them, building models, and developing theories (Houseal, 2016). The practices are intended to help strengthen students' skills and to help students develop an understanding and appreciation of the nature of science (Next Generation Science Standards Lead States, 2013). Increased engagement in the practices of science also promotes greater motivation among students to pursue STEM-related careers (National Research Council, 2012). Bybee (2011) noted the introduction of science processes in the 1960s was a major change in the method of science education. Science instruction began to widen its focus from the memorization of scientific methods to include scientific processes such as observing, clarifying, measuring, inferring, and predicting (Bybee, 2011).

Performance Expectations

Disciplinary core ideas, crosscutting concepts, and science and engineering practices are all jointly expressed in statements called *Performance Expectations* (Bybee, 2013). Performance expectations describe what students should know or do to demonstrate mastery of the standards (Willard, 2013). The performance expectations are designed to help educators develop assessments which are aligned with the intended curriculum and instruction (Next Generation Science Standards Lead States, 2013).

Pratt (2014) noted instructional plans should begin with performance expectations which provide clear connections between concepts and across disciplines. Each performance expectation was constructed by connecting content and practices to provide coherence over time. This coherence allows for a deeper understanding of the concepts and prepares students for success when studying these concepts further in college (Next Generation Science Standards Lead States, 2013). Performance expectations within the NGSS are not meant to limit the curriculum. Students should have the opportunity to continue to pursue science concepts further if there is an interest to do so (Next Generation Science Standards Lead States, 2013).

Learning Progressions

The *Framework for K-12 Science Education* (National Research Council, 2012) and the NGSS were developed with K-12 *learning progressions* in mind (Pruitt, 2014). Learning progressions are referred to as “conceptual maps” which illustrate how a student progresses from simple to more complex conceptual understanding of a concept or subject area. Learning progressions can help teachers understand how students develop and express what has been learned. There is no single type of learning progression which is suitable for all students. Movement through the learning progressions is unique for each student and dependent upon one’s individual experiences. Teachers should use learning progressions to better understand students’ academic needs while taking into account student differences (Achieve, 2015).

Pruitt (2014) advocated for the “bundling” of performance expectations when teaching next generation science. Bundling involves the grouping of similar performance expectations into sets of three. This process supports the student learning progressions and assists in making coherent connections between learned concepts and the outside world. Pruitt (2014) warned teaching the performance expectations separately could lead students to views and interpretations of science which are disconnected.

Transformational Shifts

A primary aim of the NGSS is to create an environment in which students learn about science and how things work. Bybee (2011) emphasized the focus should be on science practice rather than scientific inquiry. Science practice represents an expansion of scientific inquiry which is more engaging; for example, students may be required to experiment, collect data and evidence, operate tools, use models, and perform mathematical calculations to conduct science practice. The NGSS provides some structures science teachers can use to transform the classroom from a place where students *learn* about science to a laboratory where students *do* science (Houseal, 2016). Passmore (2015) summarized three things which must be addressed in order for this transformation to become reality: (1) the connection between content and process, (2) the relationship between the learner and the material, and (3) the role of the teacher.

The Connection between Content and Process

The NGSS vision advocates for a fusion of science content and practice. Traditionally, science classroom lessons have separated the dimensions of content and process (Passmore, 2015). Teachers can help students build powerful understandings of science concepts by focusing on important core ideas within and across the major disciplines. A focus on important core ideas within and across the major disciplines helps students understand how scientists think about the content of various fields. Students learn to use and apply knowledge to different situations when engaging with science concepts and practicing science as scientists do. Students learn the value of being able to collect and analyze evidence, create and use models, and generate explanations. Three-dimensional learning presents opportunities for students to experience and understand how practical science works and is used to solve problems (Laverty et al., 2016).

The Relationship between the Learner and the Material

The NGSS calls for students to actively engage in science practices while learning science content (Passmore, 2015). A study conducted by Aschbacher, Ing, and Tsai (2013) revealed a proportion of the students in high school science classrooms disengaged as the teaching focused more on content. Students were more motivated to learn when presented with hands-on experiences, science demonstrations, and field experiences. The relationship between the learner and the material to be learned is of critical importance. Students must *practice* science in order to become proficient science *learners* (Schatz & Fraknoi, 2017).

Active engagement in the science classroom provides opportunities for students to engage in the practice of science. *Active learning* refers to any number of ways in which students become involved in the practice of science. Students are not overly reliant on the classroom teacher when engaged in active learning (Edwards, 2015). Active learning activities are those which require students to reflect upon why concepts are used. Students are challenged to assess the understanding of concepts and the ability to address problems of relevance (Edwards, 2015). Passmore (2015) warns this could be a difficult shift, since a student's self-perceived role in learning can frame views regarding class participation.

The Role of the Teacher

A shift in the role of the student as a learner implies there must be a shift in the role of the teacher (Morrison, 2014). Teachers must set expectations for more engaged learning in classrooms in order for students to accept and take on more active learning roles (Passmore, 2015). The goal is for students to participate in active, transformative, knowledge creation processes. Therefore, teachers should facilitate and guide students in ways which emphasize information to knowledge transformational processes. Teachers should create space and time for such transformations to occur, and serve as guides for students along the way (Morrison, 2014). Instruction is most effective when teachers build upon the natural curiosity of young adolescents. Lessons infused with opportunities for problem-solving, high-level questioning, inquiry, and interdisciplinary projects can help build upon and extend the knowledge students bring into the classroom (Edwards, 2015).

Learning Models

Learning models such as the 5Es (engage, explore, explain, elaborate, and evaluate) and CER (claim, evidence, reasoning) can help teachers achieve this goal (Bybee, 2014a; Allen & Rogers, 2015).

The 5E learning model. The 5E learning model was developed more than 25 years ago by Rodger Bybee and a team of colleagues for the Biological Sciences Curriculum Study (BSCS). The model has been widely used and is now seen as one which can successfully integrate the three dimensions of the NGSS (Bybee, 2014a). The 5E learning model includes the following phases: Engage, Explore, Explain, Elaborate, and Evaluate. Each phase of the model serves a different function in teachers' instructional plans. The model helps students gain a better understanding of scientific knowledge and skills. The model helps teachers expose students to key concepts during the process of natural problem-solving. The lessons must be structured as problem situations so students can progress through the Es at a comfortable pace (Senan, 2013).

The 5E model allows students to explore scientific phenomena as well as personal, relevant questions and ideas. Students are first *engaged*. The goal of this step is to capture the students' interest. Students' interest can be captured by posing a problem, asking a question, or presenting a discrepant event. The *explore* stage follows, in which teachers provide background, materials and equipment. The teacher also counters misconceptions and helps to clarify students' understanding of important concepts. The *explain* phase is where the teacher briefly introduces scientific and technical information which may be done verbally or with the use of media such as videos or computer applications. The *elaborate* phase requires students to be involved in new situations in which the application and extension of learning can take place. The *evaluate* phase prompts teachers to expose students to experiences which are similar to those experienced in the prior stages as a means of assessment (Bybee, 2014a).

Claim, evidence, reasoning. The CER (claim, evidence, reasoning) framework is a process of teaching students how to use claims, evidence, and reasoning to support explanations for science (Jackson, Durham, Dowell, Sockel, & Boynton, 2016). The CER framework assists students in developing explanations and promotes the understanding of science through writing. The process involves the formation of statements called *claims*. This is a knowledge statement which provides the answer to a question or solution to a problem. *Claims* are based on observations which students gather as *evidence*. The *evidence* is then discussed, thereby highlighting the key scientific concepts which will help students to build a solid understanding of the science content. The CER framework can be used by science teachers to help address NGSS skills by asking students to construct explanations and communicate *reasonings* (Allen & Rogers, 2015).

When engaging in Next Generation Science, students are expected to demonstrate science practices and think as scientists do (Houseal, 2016). The CER framework supports these skills. The use of claims and evidence statements highlights the critical role of evidence in scientific reasoning. Students think like scientists when evaluating claims and evidence statements, identifying faulty claims, and deriving alternative explanations. Evidence gathered through scientific investigation is connected to basic science concepts and principles through *reasoning* statements (Jackson et al., 2016).

Constructivism and the NGSS

The NGSS builds upon constructivist ideas. Constructivism refers to the notion of students creating meaning within themselves based on experience, rather than acquiring knowledge from external sources. When constructivism is put into practice, teachers will observe students to be cognitively active, learning in context, building new knowledge upon prior knowledge, applying new knowledge, and engaging in self-reflection (Glasersfeld, 1990). There is a focus on the construction of meaning by the learner at the heart of the NGSS. This focus on the construction of meaning is accomplished through immersion in the science and engineering practices employed to grasp disciplinary core ideas and make connections to unifying science concepts. This process represents a conceptual shift in science education, as classroom experiences are needed to demonstrate how science is interconnected, practiced, and experienced in the world outside of the classroom (Next Generation Science Standards Lead States, 2013). Constructivism is a foundation on which science teachers can creatively and actively engage students in Next Generation Science.

Technology and the NGSS

Technology is defined as the application of science in *A Framework for K-12 Science Education* (National Research Council, 2012). Technology is the result of engineers using the understanding of human behavior and the physical world to develop ways of satisfying human needs and desires. Technology is an outgrowth or a product of science in the context of the NGSS (Bartholomew, 2015). Linn et al (2016) described technology as being an important influence on scientific advancement, as it shapes methodologies, models, and theories.

The NGSS opens the door to greater use of technology in the science curriculum. Technology can help students carry out investigations by creating opportunities to collect, access, and use real-time data (Krajcik, 2015). Shiang-Kwei Wang, Hui-Yin Hsu, and Posada (2014) noted the NGSS can provide students with opportunities to become fluent in 21st century 'new literacy' skills. 'New literacy' refers to the myriad of academic skills made possible through the use of technology. Examples of new literacy skills include using communication technologies to locate and identify information, as well as to assess, process, synthesize and communicate information to others. The International Technology and Engineering Educator's Association (ITEEA) conducted a study which found schools in several states required some form of technology and engineering education (Moye, Jones, & Dugger, 2015). The NGSS are expected to be used as a pathway to deliver technology and engineering content to students (Moye, Jones, & Dugger, 2015).

Engineering and the NGSS

Engineering is defined in *A Framework for K-12 Science Education* as a systematic process which is used to design objects (National Research Council, 2012). The process is often iterative as the engineer may cycle through numerous rounds of design, testing, and redesign to achieve optimal performance (Boesdorfer & Greenhalgh, 2014). Technology and engineering education have traditionally been delivered by teachers of technology, engineering, or applied technology. However, researchers argue engineering education is best delivered through core science subjects, since science is based on analytical reasoning and the integration of mathematical principles, which engineering relies on heavily (Bartholomew, 2015).

The NGSS call for the incorporation of engineering practices in the science classroom. *A Framework for K-12 Science Education* dictates each performance expectation within the NGSS must incorporate a relevant science or engineering practice with a disciplinary core idea and a crosscutting concept which is appropriate for students at a given grade level. Future assessments will not only assess students' understanding of core ideas. Students' ability to use science and engineering practices will also be assessed. Students must be able to demonstrate the use of science understandings to investigate the natural world (Next Generation Science Standards Lead States, 2013).

Moore, Tank, Glancy, and Kersten (2015) conducted a case study to compare the quality of engineering education standards present in existing state science standards (before the release of the NGSS) with the NGSS. State science standards documents from all 50 US states, and the NGSS document, were analyzed using content analysis. The researchers found varying degrees of engineering education standards in the state standards of 36 states, while the other 14 had none at all. The analysis of the NGSS documents showed mention of engineering in 49 of the 208 performance expectations. There were also 76 learning goals connected to these 49 performance expectations. The researchers also found engineering concepts present to varying degrees across grade bands within state science standards documents. The grade bands of K-2 and 3-5 had limited treatment of, or did not include, engineering. Engineering was well distributed across the grade bands of 6-12.

Teachers have expressed some concern about the lack of experience in engineering and are apprehensive about incorporating engineering practices effectively into the science curriculum (Boesdorfer & Greenhalgh, 2014). Boesdorfer and Greenhalgh (2014) reported only 7% of high school teachers felt well prepared to teach engineering through science. The researchers stated the level of apprehension may be higher for other science teachers, as 28% of physics teachers have taken an engineering course compared to only 10% of other teachers of science. Boesdorfer and Greenhalgh suggested four ideas for infusing incorporating engineering into the existing science curriculum: (1) Setting up engineering experiments so engineering contexts, ideas, and terminology are included, (2) Requiring students to work to achieve optimal performance, (3) Using design loops as a tool for creating activities, and (4) Creating design briefs.

Critiques of the NGSS

Rodriquez (2015) warns about jumping on another expedient science education reform track. He urges education decision makers to pause and reflect on three claims: (1) The impact of the NRC's National Science Education Standards (NSES) on teacher practice and student performance is not known. Rodriquez argues one must have information about the impact of previous standards in order to make appropriate adjustments to new standards. (2) Equity and diversity were not taken into consideration when writing the standards. Rodriquez argues including dimensions of engagement, equity, and diversity could guide science teachers in making the science curriculum more culturally and socially relevant. (3) The Framework committee was not representative of the student population for which the standards were intended. A disproportionate number of science teacher educators and researchers contributed to the lack of social and cultural relevance of the NSES (Rodriquez, 2015).

Aschbacher, Ing, and Tsai (2014) maintain the NGSS successfully addresses student achievement, and the nature of science and its relevance to students' lives. The researchers note the standards do not address students' self-confidence as learners of science. The NGSS acknowledges the importance of student motivation, perseverance, and career awareness, but these characteristics are not emphasized in the standards (NGSS Lead States, 2013; Aschbacher, Ing, & Tsai, 2014).

NGSS Implementation

The positive changes expected in science education will ultimately depend on how the NGSS are implemented in science classrooms. Science teachers play a critical role in science education. A teacher's perceptions, attitudes, and beliefs all play a part in the curriculum which is delivered to students (Christidou, 2011). Teacher beliefs are strongly aligned with teacher practices (Schramm-Possinger, 2016). Science teacher perceptions have implications for the kind of inquiry-based teaching taking place in the science classroom (Ireland, Watters, Brownlee, & Lupton, 2012).

Haag and Megowan (2015) conducted a mixed-method study examining teachers' motivation to adopt the NGSS and the level of readiness to implement the standards. The researchers sought to uncover three things: the level of motivation expressed by teachers of grades 7-12 to use NGSS, the level of preparedness expressed by teachers of grades 7-12 to use NGSS, and whether teachers felt more motivated and prepared to use NGSS after the use of modeling instruction. High school teachers were reported to be more highly motivated than middle school teachers to employ the eight NGSS science and engineering practices and also felt more prepared to do so. Teachers who used modeling instruction in both middle and high school felt more prepared to implement the NGSS in five out of the eight practices: developing and using models, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, and engaging in argument from evidence.

Trygstad, Smith, Banilower, Nelson, and Horizon Research (2013) examined the status of elementary school science education, focusing on teacher beliefs about teaching and learning, resources for instruction, instructional practices, professional development, and school and district policies to support the teaching of science. The results suggested schools were not fully prepared to deliver NGSS-based curricula. The amount of science instruction provided to elementary school students averaged only 20 minutes per day, limiting the amount of time to engage with science concepts and practices. This study also indicated teachers had concerns about the supplies and materials needed for science instruction. A substantial portion of elementary teachers viewed themselves as unprepared to teach science concepts related to physics, chemistry, and engineering. The ideas uncovered by this study can be identified as barriers to NGSS.

The degree to which middle school science teachers are able to successfully teach science content and practices may be influenced by the kind and level of support received. Bismack, Arias, Davis, and Palincsar (2014) noted teachers will need even more support when aligning science curricula to the NGSS. Following an NGSS professional development project, Passmore (2015) summarized three key expectations teachers had of administrative leaders. Teachers noted administrators should expect questions which invoke wonder to be written on the classroom board as targets, rather than knowledge-based standards statements. Administrators should support the collaboration of teachers with each other. School leaders should expect science classes will be active and energetic, and adequate space should be provided for science learning. Administrators could contrast teachers' expectations which would lead to a reversion in teaching which focuses on content rather than problem-solving practices. Passmore (2015) highlights the contrast between traditional science teaching methods and the problem-solving practices of the NGSS. Administrative support will impact middle school science teaching practices.

Teachers are the determiners of the curriculum delivered in the classroom (Sen & Sarı, 2017). Teachers have little input in the development of educational reforms and often receive criticism for being hesitant to implement the latest educational changes (Burks, Beziat, Danley, Davis, Lowery, & Lucas, 2015). Teachers will need the support of *change-effective leaders* when implementing the NGSS. Fullan and Scott (2016) identified change-effective leaders as those who combine personal, interpersonal, and cognitive skills to effectively manage change. Such leaders possess the ability to lead while empathizing, modeling, and teaching (Fullan & Scott, 2016).

Current Stage of Implementation

The implementation of the NGSS will require large-scale changes across institutions of education. To embrace these changes, students, teachers, and educational leaders must be willing to depart from traditional views of teaching and learning. Fullan (2014) posited teacher development has a strong connection to educational change and is critical to the transformation of educational institutions. Fullan's position implies teachers must be receptive to new ideas and ways of thinking about science education in order to successfully implement Next Generation Science.

The standards represent several years of planning and collaboration among science and education leaders. Efforts to create the NGSS originated in the summer of 2011 as the lead states assembled a writing team who created the first state draft of the standards in the following fall. Several drafts of the standards were written and reviewed between the fall of 2011 and the spring of 2013. The final draft of the standards was released in April 2013 (Next Generation Science Standards Lead States, 2013).

Currently, only 18 states and the District of Columbia have adopted the NGSS (NASBE, 2017). Overall implementation has been slow compared to the adoption rate of the Common Core Standards which focus on the subjects of language, arts and math. Proponents of the NGSS note the delay was to be expected given the implementation of the Common Core Standards. It is believed most states will adopt the standards over the next several years (Heitin, 2015).

It is up to the individual state boards of education to determine the implementation timeframe and other specifics regarding how the standards will be facilitated. The state of Illinois adopted the NGSS in January of 2014. The Illinois State Board has been providing resources and professional development to help teachers and administrators prepare to make the changes in the science curriculum necessary for compliance with the standards. The NGSS were set to officially go into effect in the state of Illinois during the 2016-2017 school year (Illinois State Board of Education, 2016).

The Next Generation Science Standards represent the future of science education. The memorization of exhaustive amounts of factual information is no longer a central focus of science education. The new standards focus on content, science practices, and crosscutting concepts. The NGSS weave engineering practices into science and lay the foundation for a curriculum allowing students to engage in more open-ended inquiry-based learning. The NGSS have the potential to fundamentally alter the landscape of science education in America and prepare students for college, careers and the modern world (Achieve, 2013).

Chapter Summary

Science education has undergone tremendous transformations over the last several decades. The NGSS were introduced in 2013 and are expected to change the landscape of teaching and learning in science (Next Generation Science Standards Lead States, 2013). There will be significant departures from traditional methods of science teaching. The new standards provide opportunities to progress science education through improvements to science curricula, teacher professional development, assessment, and student performance and achievement (Bybee, 2014). The three- dimensional organization of the NGSS will provide science educators with a practical method of guiding students toward the development of critical science skills and content knowledge.

The delivery of curricula can be influenced by teacher perceptions (Christidou, 2011), as the beliefs held by teachers are strongly aligned with teaching practices (Schramm-Possinger, 2016). Hence, the perceptions of science teachers may have implications for the kind of inquiry-based teaching which takes place in science classrooms (Ireland, Watters, Brownlee, & Lupton, 2012).

Chapter 3: Research Method

The purpose of this dissertation study was to examine how middle school science teachers perceive the Next Generation Science Standards (NGSS). Examining how teachers perceive the NGSS will allow the researcher to identify the ideas and beliefs middle school science teachers hold regarding the implementation of the standards. This study's purpose prompted the development of three research questions, which were used to explore teachers' ideas and beliefs relative to the following three concepts: the seven conceptual shifts in K-12 science education, resources and supports for NGSS implementation, and barriers to NGSS implementation.

Research Questions

The guiding questions for this study were the following:

1. How do middle school science teachers perceive the NGSS?
2. What resources and support systems do teachers report as being beneficial in the implementation of the NGSS?
3. What do middle school science teachers report as being challenges or barriers to implementing the NGSS?

Research Design and Rationale

A qualitative, constructivist, grounded theory research design was employed to (1) gather information about teachers' perceptions of the NGSS and experiences with implementation, (2) identify the resources and supports effective in the implementation of the NGSS, and (3) uncover challenges in implementing the standards. The grounded theory approach was chosen because of the iterative process it entails and its open-ended approach to discovery (Andrews, Higgins, Andrews, & Lalor, 2012). Grounded theory uses "systematic, yet flexible guidelines for collecting and analyzing qualitative data to construct theories from the data . . ." (Charmaz, 2014, p. 1). Charmaz's (2014, pp. 12-13) "constructivist grounded theory" "includes the iterative logic Strauss emphasized," adopts the "inductive, comparative, and open-ended approach of Glaser and Strauss," "employs the dual emphasis on action and meaning inherent in the pragmatist tradition," and acknowledges "subjectivity and researcher's involvement in the construction and interpretation of data." A qualitative, constructivist grounded theory design is best suited to uncover middle school teachers' perceptions of the NGSS because it will allow the researcher to be open to the existence of multiple truths during the research and theory-building processes. The researcher expects this study to yield multiple findings and varying results based on individual teachers' perceptions and understandings of the NGSS (Arghode, 2012).

Cho and Lee (2014) noted grounded theory methods are appropriate to use when there is no existing theory to explain a social issue or phenomenon. Grounded theory provides a way of uncovering rich detail in qualitative data in order to systematically develop a theory about what is being studied. The grounded theory approach offers the researcher a strategy for handling large volumes of data such as those gathered from qualitative methods such as interviews, observations, and documents. This method is ideal for exploring topics in the areas of education and the social sciences which need further research (Baturina, 2015). Grounded theory is based on a premise which implies the generation of theory requires a deep understanding of social phenomena (Lawrence & Tar, 2013).

Qualitative Research

Qualitative research designs are used when a researcher seeks to understand meanings derived by participants within the population being examined (Arghode, 2012). The goal of qualitative research is to explore, understand, compare, and contrast the descriptive accounts of events by participants in a social setting (Park & Park, 2016). Rich descriptions of phenomena can be captured through qualitative research as words are used as data instead of numbers (Merriam & Tisdell, 2015). This perspective is important as the researcher seeks to identify variables which could influence how middle school science teachers approach NGSS implementation in different contexts. The use of a qualitative research design allowed research participants to respond in ways which are less limiting than if quantitative methods were used. Investigations involving the study of one's opinions, perceptions, beliefs, or values related to a social issue or problem can be appropriately addressed through the use of qualitative methods of research (Arghode, 2012).

Constructivist Research

This dissertation on middle school teacher perceptions of the NGSS was conducted from a constructivist perspective. Constructivist-based research encompasses the notion of individuals living and interacting in social contexts and developing multiple meanings from varied experiences (Creswell, 2014). Research in this paradigm assumes an individual's reality is constructed socially and there is no single reality. Rather, there could be multiple interpretations of a single event (Merriam & Tisdell, 2015). The goal of constructivist-based research is to interpret and understand the meanings others assign to social problems and inductively generate theories to explain patterns of meaning (Creswell, 2014).

A qualitative, constructivist grounded theory design is best suited to uncover middle school teachers' perceptions of the NGSS because it will allow the researcher to be open to the existence of multiple truths during the research and theory-building processes. This study yielded multiple findings and varied results based on individual teachers' perceptions and understandings of the NGSS (Arghode, 2012). The grounded theory approach was chosen because of the iterative process it entailed and its open-ended approach to discovery (Andrews, Higgins, Andrews, & Lalor, 2012).

Grounded Theory

Grounded theory was originally introduced as a method of inquiry by Glaser and Strauss in 1967 through the seminal text, *The Discovery of Grounded Theory* (cited in Birks & Mills, 2015, and Charmaz, 2014). Grounded theory is a method of qualitative inquiry in which the researcher develops theory which is based on the views or perspectives of the study participants (Creswell, 2014). The theory is one which is discovered, developed, and verified through the systematic collection and analysis of data. The grounded theory method allows the researcher to discover or generate theory from the qualitative data by following specific guidelines (Andrews, Higgins, Andrews, & Lalor, 2012). This method is both iterative and comparative in as the researcher must make constant comparisons across the different categories of data to control the level and scope of the developing theory (Sutcliffe, 2016). Three main variations of grounded theory have evolved since its initial introduction: Glaserian grounded theory, Straussian grounded theory, and constructivist grounded theory.

Glaserian grounded theory is the basic methodological approach to grounded theory originally developed by Glaser and Strauss. The method represents an attempt to discover meaning in a highly objective manner. Glaserian grounded theory emphasizes systematic data generation to build theories which vary in scope and complexity (Uri, 2015). The researcher analyzes the initial set of data and constantly makes comparisons between emerging concepts and categories. The researcher must maintain a disengaged stance, but must be open to creative discovery and the generation of a theory about the phenomenon being studied. In Glaserian grounded theory, theory generation should be unaffected by the researcher's prior knowledge (Sutcliffe, 2016; Cho & Lee, 2014).

Straussian grounded theory represents an evolution of Glaserian grounded theory. Anselm Strauss and Juliet Corbin derived a version of grounded theory which placed less emphasis on the emergence of concepts and categories and more emphasis on technique and scripted routines (Cho & Lee, 2014). The Straussian grounded theorist seeks to develop as many relevant categories as possible by asking questions which address the *who*, *what*, *when*, *where*, *why*, and *how* of the phenomenon. The researcher also utilizes theoretical codes which cover causes, conditions, contexts, contingencies, co-variances, and consequences (Uri, 2015). Straussian grounded theory acknowledges it is unrealistic to remain completely objective during the research process. This version of grounded theory is ideal for the researcher who seeks to explore and understand complex social processes through imperfect human perception and thought (Sutcliffe, 2016).

Constructivist grounded theory was derived in the 1990s by Kathy Charmaz (2014) and represents a more social and interactive approach to grounded theory (Cho & Lee, 2014). Constructivist grounded theory differs from the Glaserian and Straussian methods as the researcher's views and interpretations are critical in the process of theorizing (Uri, 2015). The constructivist approach acknowledges the researcher's socially-constructed reality which influences the research. Ongoing subjective interpretations of data are constructed based on the researcher's own experiences. The researcher's findings are interpretations which are mutually constructed by the researcher and the participants being researched (Higginbottom & Lauridsen, 2014). The constructivist grounded theory approach was selected as most appropriate for conducting the present study on middle school science teacher perceptions of the NGSS.

Role of the Researcher

The intent of a qualitative study is to explore and convey the thoughts and feelings participants have about a phenomenon under study. The qualitative methodology helps the researcher to develop an understanding of the meanings participants ascribe to experiences. It is the role of the qualitative researcher to attempt to extract this information from participants. The researcher has a primary responsibility to safeguard participants and collected data. The researcher must also communicate to participants the mechanisms by which such safeguarding will occur (Sutton & Austin, 2015).

Any connection between the researcher and the research topic provides an opportunity for bias to arise within a study. Full disclosure of the connection between the researcher and the study topic will help to mitigate the impact of this bias throughout the study (Patton, 2014). In the present study on middle school teacher perceptions, the researcher is a practicing teacher with 16 years' experience teaching in middle school science settings. The researcher has professional experiences similar to those of the research participants. In an effort to reduce conflicts of interest and researcher bias (Chenail, 2011), the researcher selected study participants from the same county in which he is employed, but excluded those with whom he has a working relationship. The researcher adhered carefully to the research protocol outlined in the following methodology when collecting and analyzing data to further reduce researcher bias.

Research Procedures

The research procedures are described in a detailed manner. The procedures described are sampling, data preparation, data storage, data collection and analysis.

Population and Sample Selection

The researcher invited teachers from middle schools in DuPage County, Illinois, to participate in this study. This county was selected due to its close proximity and subsequent ease of access to participants. DuPage County is located 20 miles west of Chicago and is the second-most populated county in the state of Illinois. The county has a population of over 916,924 people, with minority groups comprising 30%. The county has a low unemployment rate and had the highest per capita income among all counties in Illinois in 2009. The county's median household income in 2009 was $73,520. The DuPage County public school system is composed of 29 elementary school districts, seven high school districts, and six community unit districts (Department of Economic Development and Planning, 2011). The *Public School Review* (2016) identified 59 middle schools within DuPage County.

The researcher contacted the superintendents or district leaders of each of the 59 middle schools during the fall of 2017 using the *Letter to School District Superintendents* (Appendix B). This initial letter was emailed to school superintendents and school principals in order to introduce the researcher and explain the title, purpose, and scope of the study. The letter asked for administrative permission to contact the middle school science teachers within each district and request participation. The email contained a link which directed the superintendents and principals to an online response form where administrators could grant or deny permission. Data from this form was automatically sent to a confidential, password-protected spreadsheet held by the researcher. Administrators were given one week to respond before a follow-up email was sent.

Once permission was obtained from the superintendents or principals, the *Letter Requesting Science Teacher Participation* (Appendix C) was sent to middle school science teachers to introduce the researcher and explain the title, purpose, and scope of the study. As before, a link in the email directed teachers to an online response form where teachers could accept or decline to participate, or request more information. Data from this form was automatically sent to a confidential, password-protected spreadsheet held by the researcher. Middle school teachers will be given one week to respond before a follow-up email is sent. Science teachers who immediately agreed to participate in the study were directed to the *Informed Consent Form* (Appendix A), which teachers were asked to submit within one week. Teachers who submitted the *Informed Consent Form* were directed to the *Middle School Science Teacher Perceptions Survey* (Appendix D), and were asked to complete and submit the survey within one week. The survey responses were sent to a confidential, password-protected spreadsheet held by the researcher.

The returned surveys represented a pool from which interview participants were selected. The researcher engaged in the process of theoretical sampling when selecting interview participants (Robinson, 2014). The researcher selected participants to interview based on survey results and participants' willingness to elaborate on personal experiences related to NGSS implementation. Participants selected for interviews were asked to share a sample of an NGSS-based lesson which had been recently used in the classroom.

A purposive sampling strategy was used in this study. Purposive sampling methods are commonly used in qualitative studies to allow for specific categories of cases within a sampling universe to be represented (Robinson, 2014). Participants selected through purposive sampling are chosen based on the anticipated relevance and richness of the information relative to the study's research questions (Gentles, et al., 2015). A specialized form of purposive sampling used in grounded theory studies is theoretical sampling (Robinson, 2014). Theoretical sampling takes place during data collection but after it has started. The sample size can be increased if initial data analysis leads the researcher to believe more information is needed from a particular group in order to enhance the validity of the emerging theory or findings (Robinson, 2014).

Robinson (2014) said grounded theory research designs emphasize flexibility in a study's sample size. Creswell (2014) noted qualitative research, which includes grounded theory methodology, typically has a sample size within the range of 20 to 30 individuals. The researcher's goal was to acquire a sample size sufficient enough to produce theoretical saturation. Theoretical saturation occurs when further data collection no longer proves beneficial to the process of theory development (Gentles et al., 2015). Robinson suggested smaller sample sizes should be used in qualitative research so individual cases can have a voice within the study and so an in-depth analysis of each case can be conducted. Gentles et al (2015) noted sample sizes of six or less rarely provide enough data to produce theoretical saturation. The researcher initially sought a sample of 20 participants for the semi-structured interviews which was based on Creswell's sample size suggestions for grounded theory studies. The researcher planned to adjust the number of participants to include more if theoretical saturation was not reached with the initial sample of 20 participants.

Instrumentation

The researcher used surveys, semi-structured interviews, and documentary sources to gather qualitative data for this study on middle school science teacher perceptions of the NGSS. All questions used in the surveys and interview protocol were developed by the researcher. The development of these questions was guided by consideration of the characteristics of the seven conceptual shifts outlined in the NGSS (Next Generation Science Standards Lead States, 2013).

Surveys. The *Middle Level Science Teacher Perceptions Survey (MLSTPS)* (Appendix D) was administered to middle school science teachers. The survey consisted of both closed-ended and open-ended questions. The design of the survey was clear, convenient and functional, as the researcher's goal was to elicit the maximum number of responses possible from the initial interaction with teachers (Baatard, 2012). The closed-ended questions required responses according to a five-point Likert-type scale. Likert-type scales are commonly used in social science research to collect data on respondents' behaviors or attitudes (Edmondson, Edwards, & Boyer, 2012). Open-ended questions were also used to allow teachers to express perceptions and ideas more freely (Lowe & Zemliansky, 2011). The survey aided the researcher in identifying a teachers' teaching experience, current grade level, level of NGSS familiarity, NGSS training, and comfort level with implementing NGSS.

Interviews. Semi-structured interviews were used to gain in-depth information about middle school science teachers' perceptions of the NGSS and levels of comfort with next generation science teaching practices. The semi-structured interviews also assisted the researcher in gathering ideas from middle school science teachers about the challenges faced when implementating the NGSS and the resources provided to support implementation. These interviews aimed to elicit rich, detailed, qualitative descriptions of teachers' beliefs, perceptions, and experiences. Interviewing study participants helped to create deep contextual accounts of experiences as well as participants' interpretations of those experiences (Doody & Noonan, 2013).

Extant Data Source. Each middle school science teacher was asked to share a current lesson plan for a next generation science-based lesson or a sample of a key next generation science activity which was created and implemented in the science classroom. A limit of one lesson plan or activity per teacher was set as more might produce an unmanageable amount of data and contribute to analytical overload (Robinson, 2014). Evidence was sought related to the implementation of NGSS engineering practices and for validation of survey and interview data.

Instrument Development. The questions used for the initial survey and semi-structured interviews of middle school science teachers were developed by the researcher and were relevant to the broad phases of NGSS implementation (California Department of Education, 2014). In the development of these questions, the researcher also referred to the expectations described in the seven conceptual shifts outlined in the NGSS (Next Generation Science Standards Lead States, 2013). It was important for the researcher to refer to both of these resources to guide question development for the survey and the semi-structured interview protocol to ensure the data generated from the study would be relevant to the main research questions. The *Middle School Science Teacher Perception Survey* (*MLSTPS)* (Appendix D) contained 26 Likert-type scale questions and three open-ended questions. The *MLSTPS* consisted of 23 interview questions.

Data Collection

Survey Monkey was used to collect the initial responses of middle school principals, and teachers' responses to the *MLSTPS*. *Survey Monkey* is an online data handling resource which allows researchers to create and administer surveys and questionnaires (Wilson, 2013). Each survey participant was assigned a unique code which did not include any personal or professional identifying information. This code ensured the participant's anonymity (Baškarada, 2014). Participants used this code when responding to the survey. Survey responses were automatically sent to a confidential spreadsheet held by the researcher once the respondent submitted the survey.

The researcher contacted each interview participant by email to determine the preferred interview method. The semi-structured interviews were all conducted by phone. Semi-structured interviews offer the researcher some flexibility in exploring new, emerging paths during the interview process which may not have been considered beforehand (Doody & Noonan, 2013). Probes or prompts were used when necessary during the semi-structured interviews. Probes provide the opportunity to clarify participants' responses by asking follow-up questions (Doody & Noonan, 2013). The researcher completed interviews with each participant within a period of one month. Each interview was recorded using an audio recorder and held in confidence by the researcher. Recording the interview session served as one way to eliminate bias (Lowe & Zemliansky, 2011). Recordings and notes taken during and after each interview were labeled with participants' codes to ensure anonymity. All interview notes were stored in a locked filing cabinet during and after the research process.

The researcher also used an extant, text-based data source to supplement the survey and interview data. Charmaz (2014) noted an extant text is one which is not dependent on or affected by the researcher. Researchers may use an extant text source because it is readily available, objective, and is unobtrusive (Charmaz, 2014). Each middle school science teacher was asked to share a current next generation science lesson or a sample of a key next generation science activity created and implemented in the science classroom. A limit of one lesson or activity per teacher was set, as more might produce an unmanageable amount of data and contribute to analytical overload (Robinson, 2014). Evidence was sought regarding the implementation of NGSS science and engineering practices and which validates the survey and interview data

Data Preparation

Data collected using the *MLSTPS* (Appendix D) was organized into a spreadsheet format through *Survey Monkey*. The researcher ensured only the assigned research codes are used to identify each participant represented on the spreadsheet. Interviews with participants were recorded with permission from the participant. The recordings were transcribed by the researcher so common themes could be more easily identified. Lesson samples collected from interview participants were organized so the instructions for students could be easily viewed and compared.

Data Analysis

The survey responses, interview notes, and curricular documents gathered for this study were analyzed using grounded theory analysis methods. Grounded theory processes of data collection and analysis continue in a cyclical nature until a theory is derived from the data (Higginbottom & Lauridsen, 2014). Birks and Mills (2015) outlined several essential steps in grounded theory data analysis, including: initial coding and data categorization; concurrent data collection and analysis; memo writing; theoretical sampling; constant comparative analysis; theoretical sensitivity; intermediate coding; identification of a core category; advanced coding; and theoretical integration (Birks & Mills, 2015). This process was essential in this study, as it helped integrate data obtained from different sources. The data was examined to discover relationships between categories which were used as a framework for generating core concepts which further explained the phenomenon being studied (Sutcliffe, 2016).

The first step in data analysis is the initial coding of the data. Coding, in grounded theory analysis, involves a process in which the researcher combs through the data to identify relevant characteristics and categories. Important words and phrases within the data will be identified and assigned labels (Sutcliffe, 2016). Exact words or phrases used by research participants may be used as labels, and categories of data will be established which include groups of related codes (Birks & Mills, 2015). Sutcliffe identified three levels of coding: open coding, axial coding, and selective coding. Data is broken down into broad themes through open coding. Connections between the themes are established to form higher categories through axial coding. Selective coding involves the selection of a higher category and exploring its relationship to other categories (Sutcliffe, 2016).

Grounded theory research is different from other qualitative methodologies because data collection and analysis can occur concurrently (Birks & Mills, 2015). In this study, the researcher collected an initial set of data from the participants, then analyzed and coded it. More data was collected as needed, and the analysis and coding steps were repeated (Birks & Mills, 2015). Middle school teacher survey data was coded and analyzed first. This guided the researcher in selecting middle school teacher participants for the semi-structured interviews.

Theoretical sampling is also a key component of grounded theory research (Birks & Mills, 2015). Theoretical sampling differs from initial sampling because it involves a researcher establishing sampling criteria for participants before engaging in the research (Charmaz, 2014). Theoretical sampling takes place after initial sampling and involves the researcher making an informed decision about which data sources which will be most informative with respect to the research questions (Birks & Mills, 2015). The gathering of data is guided by emerging themes in prior stages (Sutcliffe, 2016). The theoretical sampling process first involves an initial analysis of data. Tentative ideas are then constructed and examined through further inquiry (Charmaz, 2014). The researcher continues the theoretical sampling process until the properties or characteristics of each identified category have been fully developed (Birks & Mills, 2015).

Writing memos is helpful during the theoretical sampling process. Memo writing is an intermediate step between the collection of data and the writing of research paper drafts. Writing memos forces the researcher to pause and analyze ideas about the codes which have been formed early in the research process (Charmaz, 2014). The research agenda can be diagrammed and planned with the assistance of memos (Birks & Mills, 2015). Memo writing helps capture the thoughts, connections, and comparisons made by the researcher (Charmaz, 2014). A researcher's memos provide a detailed record the thoughts and decisions made during the research process. Questions and potential paths for future inquiry can be solidified and formalized through this process (Charmaz, 2014). Memoing is a continuous activity for the grounded theory researcher.

Middle school teachers were selected for semi-structured interviews based on the information gathered from the teacher surveys. The researcher compared and contrasted the ideas and themes emerging from the survey data using the open coding process described earlier (Sutcliffe, 2016). The theoretical sampling processes described earlier was applied to determine which teacher participants were best suited to engage in semi-structured interviews. The interviews with teacher participants were recorded, transcribed, analyzed, and coded. The researcher continued to collect and code data in a recursive process, eventually employing axial coding to derive higher categories of data and selective coding to arrive at core categories of data (Sutcliffe, 2016; Charmaz, 2014).

Grounded theory research is an inductive form of research in which theory is constructed from collected data. A constant comparative analysis of the data allows the researcher to carefully derive a theory (Birks & Mills, 2015). Constant comparative analysis refers to the constant interaction between the processes of analysis and data collection (Mayer, 2015). This is important because the developing theory should represent a set of concepts which are well-developed, related, and supportive of a framework which can explain or predict a phenomenon (Charmaz, 2014). The researcher used data gathered from this study to develop a theory explaining how middle school science teachers view the NGSS. The theory further addressed why teachers have varying levels of success as the NGSS are implemented.

Birks and Mills (2015) described how the grounded theory researcher should systematically compare words or observations to codes, codes to codes, codes to categories, and categories to categories. This series of comparisons is a key aspect of grounded theory research. Axial coding allows the researcher to connect smaller sub-categories to create full individual categories. The process also serves to help the researcher make connections between categories. Axial coding increases the level of analysis which can take place as the researcher moves toward the development of a theory. A core category is then chosen through selective coding which explains the evolving grounded theory (Birks & Mills, 2015). More theoretical sampling and coding is done until the core category is saturated. Theoretical saturation is the point at which no new properties or dimensions emerge from the data (Sutcliff, 2016).

The development of a theory also relies on the researcher's level of theoretical sensitivity. Theoretical sensitivity refers to the researcher's degree of insight into self and the area of research (Birks & Mills, 2015). A researcher who is theoretically sensitive possesses the capacity to understand and give meaning to data within a study (Higginbottom & Lauridsen, 2014). Charmaz (2014) also noted grounded theory, from the constructivist perspective, acknowledges resultant theory as an interpretation of the researcher.

Samples of Next Generation Science lessons which teachers have tried or implemented were also requested based on emergent information from the semi-structured interviews.

Charmaz (2014) referred to this kind of data source as an *extant text source*. This text source was analyzed using the coding process described for the semi-structured interviews. Comparisons were made after the researcher evaluated each lesson using the Educators Evaluating the Quality of Instructional Products (EQuiP) Rubric (NGSS, 2014).

The EQuiP rubric was developed and released in 2014 in response to teachers' recognition of the lack of NGSS-aligned materials (NGSS, 2014). The EQuiP rubric consists of three categories: alignment to NGSS, instructional supports, and monitoring student progress (Ewing, 2015). The purpose of the EQuiP rubric is to: (1) review lessons or units to determine what revisions are needed; (2) provide constructive feedback and suggestions to developers; (3) inform the development of new lessons or units; and (4) identify models for teachers to use in and across states. The rubric is currently being used more for the first three purposes than to identify exemplars (Ewing, 2015). The rubric can help identify the level to which lessons are aligned to the NGSS (NGSS, 2014).

Reliability and Validity

A key property of qualitative research is to synthesize textual data and recognize patterns among words in order to construct meaning about a phenomenon without compromising its integrity and richness. Issues of subjectivity and context have fueled debate about the quality and trustworthiness of qualitative research (Leung, 2015). Quality plays an integral role throughout all stages of formal research (Ali & Yusof, 2011). The quality of qualitative research can be assessed in terms of validity and reliability (Leung, 2015). Creswell (2014) noted reliability and validity have different meanings in qualitative and quantitative research.

One method of ensuring the credibility and reliability of a qualitative study is by triangulation (Yilmaz, 2013). Triangulation refers to the use of several types and sources of data to investigate a research question. Using more than one type and/or source of data enhances confidence in the research findings. The focus of the study becomes more apparent when data is acquired from multiple participant or observer perspectives (Mayer, 2015). Triangulation becomes very useful in qualitative research since there are no statistical methods for demonstrating reliability and validity. Triangulation helps to provide a deeper understanding of what is being studied and strengthens the credibility and dependability of a study (Netenda, 2012). In this study, triangulation was employed by consolidating data from surveys, interviews, and lesson samples.

Qualitative reliability refers to the ability to replicate the processes and results of a study (Leung, 2015). Yilmaz (2013) referred to this as the *dependability* of a qualitative study. Consistency in data is what the researcher should strive for when conducting a qualitative study. The data and information collected during a reliable qualitative study should produce similar results if the study is replicated. Triangulation is one way to address the reliability of a study (Mayer, 2015). Another method of ensuring reliability is through constant data comparison (Leung, 2015). In the present study, a grounded theory research design incorporating continuous comparisons of data was used. Methods of checking for reliability in qualitative studies include checking for mistakes in transcripts and avoiding shifts in code meanings (Creswell, 2014). The researcher used these methods to increase the dependability of the present study.

Internal validity refers to a researcher's efforts to employ certain methods to ensure the accuracy of findings (Creswell, 2014). Leung (2015) stated validity in qualitative research refers to the appropriateness of the research. Yilmaz (2013) said the credibility of a qualitative study depends on the extent to which trustworthy methods of data collection are used. The research question must be appropriate for the desired outcome. The methodology should be appropriate for answering the research question. The sampling and methods of data analysis should be appropriate for the research design. The results and conclusion should also be appropriate for the sample and the context (Leung, 2015). The researcher increased the validity of the present study by using data collection methods appropriate for the study's questions. The researcher also provided detailed explanations of the data collection and analysis methods. The researcher established a habit of documenting practices and procedures in detail in order to capture the most accurate representation of each interaction between the researcher and the participant.

Transferability refers to the applicability of a study's findings to other similar settings (Yilmaz, 2013). Qualitative studies are designed to study a specific phenomenon within a certain population. The ability to transfer the findings of qualitative studies can be controlled pragmatically by employing systematic sampling, triangulation, constant comparison, and proper documentation (Leung, 2015). Transferability can also be achieved by providing detailed descriptions of the setting, context, actions, or people being studied (Yilmaz, 2013). In the present study, the researcher asked questions which elicited rich, descriptive responses from participants in order to increase the transferability of the study.

Ethical Procedures

The researcher obtained permission to conduct research with middle school science teachers by contacting the superintendent for each school district in DuPage County, Illinois. The title, purpose, and scope of the study was be explained by the researcher. Once permission was granted, prospective middle school teacher participants were contacted and those who agreed to participate were provided with the *Informed Consent Letter* (Appendix A). Each teacher was provided with a link to complete the *Middle School Teacher Perceptions Survey MLSTPS* (Appendix D) once the completed and signed *Informed Consent Letter* was received by the researcher. Informed consent protects the rights of participants who are involved in the research study (American College of Education, 2015).

Federal regulations enforced by Institutional Review Boards (IRBs) stipulate the privacy of participants must be protected; and participants must be protected from harm. Data gathered from participants must also be held confidentially (American College of Education, 2015). Each study participant was fully informed before giving written consent and assigned a unique participant code. The code included the current year followed by a dash and a number from 1-30. Once a participant agreed to participate in the study, the code was assigned through email. The participants were asked to enter this code when responding to the online survey. This same code was used to label interview notes and lesson samples. All data was collected electronically and was protected by a password. The researcher created an unshared file which links each participants' name to an assigned code. This file was housed in an electronic password protected file accessible only to the researcher. Participants' survey responses, interview notes, and lesson samples was housed in a locked file cabinet.

The names of participants were not used when presenting the results of this study in order to ensure each participant's privacy (American College of Education, 2015). No exact quotes from participant responses will be used in the research report without consent, as exct words could conceivably reveal participants' identity. Participants were contacted by email to request the use of excerpts from the surve and interview responses. The researcher referred to participant codes in all written and oral presentations of this study. Survey responses, interview notes, and lesson samples were destroyed at the conclusion of the study.

Chapter Summary

Teacher beliefs about educational policies can influence the implementation of those policies (Savasci & Berlin, 2012). Examining middle school science teachers' perceptions of the NGSS will provide information regarding teacher beliefs, interpretations, and needs with respect to the implementation of the standards. Studies focusing on teacher perceptions have indicated there is a connection between teachers' beliefs about pedagogical practices and the approaches used in the classroom (Schramm-Possinger, 2016). A grounded theory methodology was appropriate for this study on middle school science teacher perceptions of the NGSS. It revealed valuable information beneficial to the field of science education.

Data sources such as surveys, semi-structured interviews, and lesson samples provided rich data which was analyzed using the grounded theory method. Grounded theory is a method of qualitative inquiry in which the researcher develops theory based on the views or perspectives of study participants (Creswell, 2014). This method is both iterative and comparative because the researcher must make constant comparisons across different categories of data to control the level and scope of the developing theory (Sutcliffe, 2016). Grounded theory provides a way to uncover rich detail in qualitative data in order to systematically develop a theory about what is being studied (Cho & Lee, 2014).

Chapter 4: Results

The purpose of this qualitative grounded theory study was to examine middle-level science teacher perceptions of the Next Generation Science Standards (NGSS). Gathering teacher perceptions allowed the researcher to understand how middle and junior high school science teachers internalized and interpreted the standards when planning instruction, and how they translated the standards into classroom practices. The study also sought to identify factors teachers commonly reported as being assistive during the implementation of the NGSS, and those which served as challenges or barriers.

This study used a grounded theory approach which allowed the researcher to analyze participant responses and data according to an iterative process which facilitated open-ended discovery, as described in Andrews, Higgins, Andrews, and Lalor (2012). The guidelines for grounded theory studies allow for flexibility in collecting, analyzing, and constructing theories from qualitative data (Charmaz, 2014). Constructivist grounded theory involves iterative logic, an open-ended approach, emphasizes action and meaning, and recognizes the subjectivity of the researcher in the interpretation of data (Charmaz, 2014).

A qualitative, constructivist grounded theory design was considered best suited to investigate middle-level teachers' perceptions of the NGSS. This approach allowed the researcher to be open to the existence of multiple truths during the research and theory-building processes. This chapter presents participant demographics, the data analysis procedures, and findings from this qualitative study. Data were collected from 15 middle-level science teacher participants from within and near Dupage County, Illinois. The data sources included surveys, interviews, and sample science lessons.

This qualitative grounded theory study was guided by three research questions:

1. How do middle school science teachers perceive the NGSS?
2. What resources and support systems do teachers report as being beneficial in the implementation of the NGSS?
3. What do middle school science teachers report as being challenges or barriers to implementing the NGSS?

Data Collection

Data for this study was collected through the following processes: completion of the *Middle Level Science Teacher Perception Survey* (Appendix D), telephone interviews, and the sharing of a recent lesson or plan related to the NGSS. The Survey Monkey website was used to gather and organize the responses of school administrative leaders. Administrative leaders of 54 middle and junior high schools in DuPage County were contacted and informed of the study through email in the fall of 2018. A web link to the *Principal Response Form* was provided, through which each administrative leader provided their school's name and indicated whether or not permission to contact science teachers was granted to the researcher. A total of 18 administrators responded to the researcher's request, of which 16 granted permission.

Science teachers at each of the participating schools were contacted by email and informed of the study. The email included a detailed explanation of the study, a web link to the *Informed Consent Letter* (Appendix A), and a web link to the *Middle Level Science Teacher Perception Survey (MLSTPS)* (Appendix D). Teachers were instructed to first complete and submit the *Informed Consent Form*. Teachers then completed the *MLSTPS*. Each teacher was assigned a unique identification code and was instructed to use it instead of their actual name when participating in this study.

Fifteen teachers responded and completed the *Informed Consent Form* for the study. All

15 respondents also completed the *MLSTPS*. Each teacher who completed the survey was contacted by the researcher and asked to participate in a semi-structured interview. Participants chose the interview time and an interview method that most convenient and comfortable. Seven of the 15 teachers who completed the initial survey agreed to participate in a 15-minute interview. During the semi-structured interview, teacher participants were asked to share an example of an NGSS-related lesson which had recently been used in the classroom. Lesson and lesson plan information was submitted to the researcher by email. All data for this study was collected over a period of three months between November 28, 2017 and February 28, 2017.

The Participants

Participants for this study were all middle-grade science teachers. The middle grade level includes teachers of the sixth, seventh, and eighth grades. The teachers selected for this study were all affiliated with school districts within or on the periphery of Dupage County, Illinois. All teachers who participated in this study had some form of professional development related to the NGSS. Professional development for the participants ranged from school district level workshops to large-scale organizational training events, such as those offered by the Dupage County Regional Office of Education and Fermilab National Accelerator Laboratory's Science Education Center. Eleven teachers participated in this study, with teaching experience ranging from 6–32 years. Table 1 presents a summary of participant demographics.

Table 1

Demographics of Participants

Participant & Implementation Stage	Participant Code	NGSS Training (hours)	Grade	Science Subject Area
P: 1 p	2017-30-1	~ 8	5th and 8th	Chemistry, Space, Earth
P: 2 p	2017-29	> 50	8th	Life, Physical, Earth, General
P: 3 p	2017-27	~ 30	8th	Physical, Earth, Life
P: 4 f	2017-15	15	7th	Life, Earth, Physical
P: 5 p	2017-50	25	6th – 8th	General
P: 6 p	2017-40	> 50	5th and 6th	General
P: 7 p	2017-32	~ 100	7th	General
P: 8 p	2017-30	> 10	6th	Life, Earth, Space, Physical, General
P: 9 f	2017-33	~ 40	6th – 8th	General
P: 10 f	2017-47	100	6th – 8th	General
P: 11 p	2017-41	50	6th – 8th	General
P: 12 f	2017-75	6	6th – 8th	General
P: 13 f	2017-71	> 40	6th – 8th	General
P: 14 p	2017-62	> 20	6th – 8th	General
P: 15 d	2017-76	15–20	7th	Physical, Earth

Note: The Implementation Pathway Model stages: initial exposure, deepening understanding, planning and instruction, and full alignment letters i, d, p, and f.

Participant 2 taught chemistry, space, and earth sciences for 14 years to students in 5th through 8th grades. The participant was "pretty familiar" with the NGSS and had engaged in a variety of different NGSS-related training experiences, including roundtable discussions and district curriculum planning and development. Participant 2 estimated they had received eight hours of formal NGSS training.

Participant 3 had a 32-year teaching career and had taught life, physical, earth, and general sciences to 8th grade students. When asked about their level of familiarity with the NGSS, the following was expressed: "I guess people would say, 'Gee, you're pretty familiar,' but to be honest, the more I look at it in some ways the less it makes sense… I have to admit, when we're looking at next year with some of the things, we look at it, we read the language and it's like, ‘What the heck? How in the world are we supposed to do that?’” Participant 3 had had over 50 hours of formal training related to the NGSS.

Participant 6 was an 8th grade teacher with six years of experience teaching physical, earth and life sciences. This participant had been involved in approximately 30 hours of training related to the NGSS. When asked to describe their level of familiarity with the NGSS, the following was stated: “My level of familiarity with the NGSS, I have to say, 1-5 scale, I probably say like a 4.3. I’m pretty familiar with it but obviously, I didn’t write the standards. I’m not perfect in them by any means.”

Participant 8 had 24 years of science teaching experience and currently teaches 7th grade life, earth, and physical sciences. This participant reported having 15 hours of professional development training focused on the NGSS. The following was expressed when asked about the level of familiarity with the NGSS: “I am pretty familiar with NGSS standards. My department has been working with them for about four years now.”

Participant 10 had attended more than six conferences on NGSS-related topics and acquired over 50 hours of training. This participant had collaborated with educators from other schools on “phenomena lesson planning” and unit planning.

Participant 11 had taught 5th and 6th grade science for 21 years. This participant had attended over six conferences and engaged in over 50 hours of NGSS professional development. The following was stated regarding their familiarity with the NGSS: “I think I'm pretty familiar with it because we've been going from the basics all the way to the broad, general view of all the levels. I feel like I have a good understanding of what the students need to know before me and after me, in most of the things I'm teaching.”

Participant 1 had taught life, earth, space, physical, and general sciences for 26 years at the middle school level. When asked about their level of familiarity with the NGSS, they said: “I feel, in talking to other teachers and going to workshops, that I'm fairly familiar, but I am confused even so.” Participant 1 had more than ten hours of formal professional development and training focused on the NGSS.

Participant 7 had taught 7^{th} grade general science for 11 years and had approximately 100 hours of training and professional development related to the NGSS. The following was expressed with regard to their familiarity with the NGSS: “I would say very, very familiar. I worked a lot with unpacking them, writing units. I did write a unit with SBE. I tried to do, just for no other reason but because I'm interested, set the readings and keep up with the newsletters and the blogs that come out on NGSS. I would say very familiar.”

Participant 4 had over 40 hours of NGSS training. This participant expressed the following with regard to the implementation process: “We started this journey in 2014 as a team of teachers. We keep adjusting as we go.”

Participant 5 reported having 100 hours of NGSS-related training. This participant had extensively researched the standards for several years. The following was expressed in regard to the implementation of the standards: “This year is my 6^{th} year with NGSS…Yes, 6^{th}! I was researching the same material as the writers and implementing before NGSS came to being.”

Participant 9 had four years of teaching experience in the current district. This participant reported having 25 hours of NGSS training. The following was expressed about NGSS implementation: “I have been at my district for four years and have a department chair who is very NGSS savvy and pushes us to learn and implement the standards.”

Participant 12 reported having six hours of NGSS training and had been trained extensively by a mentor teacher. The following was expressed about the implementation process: “Every unit for the last two years has been developed and taught using the storyline process.” This participant is also working to develop storylines for a local university.

Participant 13 had acquired over 40 hours of NGSS-related training. The participant’s professional development experiences included NGSX Storyline Training and NSTA National Conference attendance.

Participant 14 was on the district Science Curriculum Team and had attended a variety of NGSS workshops related to philosophy, resources, and assessment, totaling over 20 hours. This participant was in year 3 of an NGSS pilot program and was engaged in revising units and assessment, and conducting gap analyses with respect to local needs and norms.

Participant 15 had taught 7th grade science for more than ten years. This participant had acquired between 15–20 hours of NGSS training and had participated in curriculum planning, assessment writing, and science resource selection processes with the district’s science committee.

Data Analysis and Results

Each participant’s current level of implementation was identified using the NGSS Implementation Pathway Model (Figure 1), which was developed and proposed by the states which led the development of the NGSS to facilitate its phasing-in (California Department of Education, 2014). The NGSS Implementation Pathway Model identifies three broad phases in the standards implementation process: awareness, transition, and implementation. Teachers are expected to progress through four more specific stages as they move from awareness of the standards to implementation of the standards. The more specific stages include: initial exposure to NGSS, deepening understanding of NGSS, planning instruction around NGSS, and full alignment of instruction to NGSS (California Department of Education; Spiegel, Quan, & Shimajyo, 2014).

Phase	**Awareness**	**Transition**		**Implementation**
Stage	Initial Exposure to NGSS	Deepening Understanding of NGSS	Planning Instruction around NGSS	Full Alignment of Instruction to NGSS
Participants		P15	P1, P2, P3, P6, P7, P9, P10, P11, P14	P4, P5, P8, P12, P13

Figure 1. NGSS Implementation Pathway Model

All participants recognized themselves as being at stages within the transition and implementation phases. Most teachers (60%) identified themselves as being at the planning and instruction stage. Fewer teachers (33.3%) recognized themselves as being in full instructional alignment with the NGSS (Figure 2). The smallest percentage of teachers (6.67%) from this sample identified themselves as being in the stage in which a deepening of understanding of the NGSS was taking place.

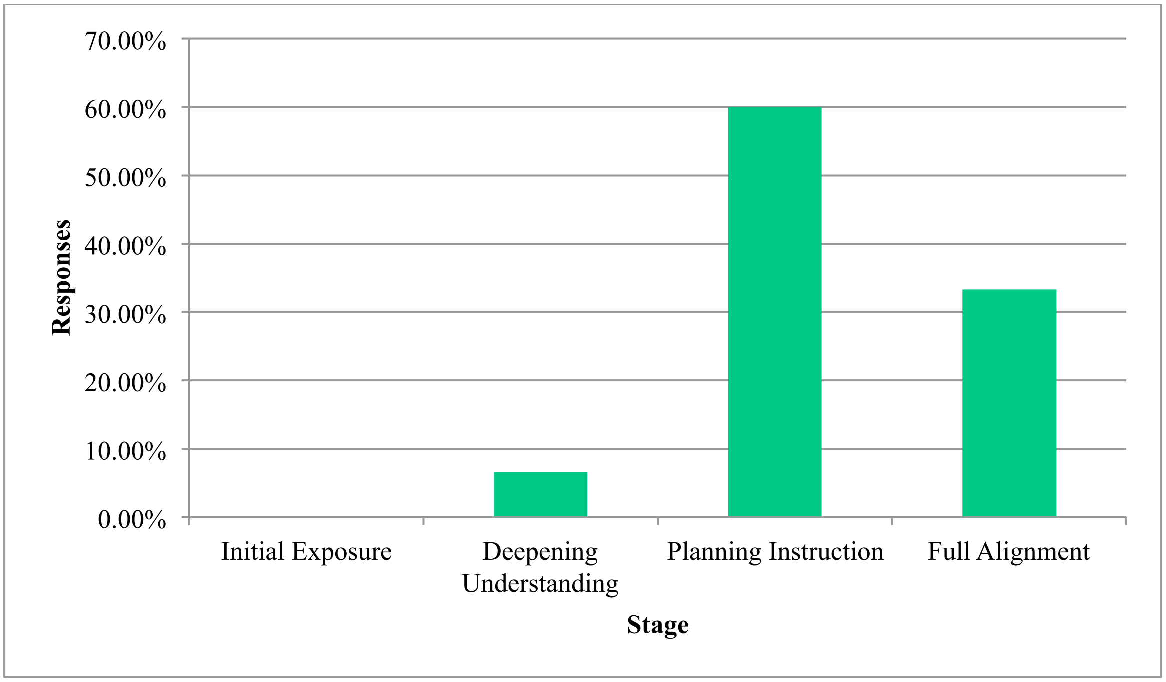

Figure 2. Level of NGSS Implementation - Based on NGSS Implementation Pathway Model

The *Middle Level Science Teacher Perception Survey* (Appendix D) was created and administered to address Research Question 1: How do middle school science teachers perceive the Next Generation Science Standards? The survey was administered to each participant through Survey Monkey. This survey was designed based on the expectations described in the seven conceptual shifts outlined by the writers of the NGSS. The seven conceptual shifts represent a change in the way teachers must think about teaching and learning in the science classroom (Pratt, 2013). Examining data relative to these questions will help the researcher compare teacher perceptions of the NGSS to the seven conceptual shifts. The *Middle School Science Teacher Perception Survey* contained three open-ended questions and 26 Likert-type scale questions. Teacher participants were instructed to select one of 5 responses to each question: Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D) or Strongly Disagree (SD). The 26 Likert-type scale questions were divided into seven sections. Each section's questions addressed one of the 7 conceptual shifts expected of science educators during the implementation of the NGSS.

Responses to questions from the survey were organized into seven tables. Each table reflects the percentage of responses at each point of the 5-points Likert-type scale for each question. The questions were organized by their relevance to each of the seven conceptual shifts in science education. Tables 6-12 (Appendix G) provide a summary of how participants responded to questions relative to the seven conceptual shifts.

The *Middle Level Science Teacher Interview Protocol* (Appendix E) consisting of 23 questions for the semi-structured interview was used to gather more in-depth responses from the participants. The interview questions were also created using the seven conceptual shifts in science education as a guide. The questions were divided into seven sections with each section containing one to five questions. Each section of questions on the interview protocol corresponded to one of the seven conceptual shifts. Each section of questions within the interview protocol was closely aligned to the corresponding section of questions on the survey

Data and information gathered through the semi-structured interviews were analyzed using processes of grounded theory analysis. Grounded theory analysis allowed the researcher to continuously analyze pieces of data until a viable theory was derived (Higginbottom & Lauridsen, 2014). Data from interview protocol were transcribed and coded. The researcher engaged in a process of coding in which the interview responses were thoroughly examined to identify relevant characteristics and categories.

The EQuiP (Educators Evaluating the Quality of Instructional Products) Rubric was used to examine lesson samples submitted by teachers. The EQuiP Rubric aides in the examination of lessons in three areas: alignment to the NGSS, instructional supports, and monitoring student

Table 2

Emergent Themes Related to the Research Question 1

Research Question 1: **How do middle school science teachers perceive the Next Generation Science Standards?**	
Conceptual Shift:	**Emergent Themes:**
Science education must show real-world interconnections in science.	- teaches problem-solving - promotes student engagement - enhances science reasoning skills
The standards represent student outcomes.	- reduction in traditional testing - create opportunities for formative assessment - encourage use of performance-based assessment
Science concepts should build progressively across grade levels.	- impacts teaching and learning at the middle school level - collaboration across grade levels helps guide curriculum development at the middle level
The standards must focus on deeper understanding and application of content.	- can promote student engagement - can be challenging to achieve in practice - should be a balance between the teaching of content and skills
Science and engineering must be integrated in science education	- promotes engagement - teaches problem-solving - enhances science reasoning skills - engineering goes beyond just building - challenges students' level of perseverance
The standards must prepare students for college, careers, and responsible citizenship	- deficiency in preparation for college readiness - does not prepare students for responsible citizenship - will take time to accomplish
The standards must coordinate with Common Core Math and Language Arts Standards.	- creates similar expectations between classes - improved performance in all subject areas - students learn to communicate science knowledge - coordination with Common Core is good but should not be a priority

progress (NGSS, 2014). The researcher used the EQuiP to examine the alignment of teacher lessons to the NGSS.

Creswell (2014) noted textual data collected during a qualitative study is dense and rich. Not all of the data collected during a qualitative study may necessarily be used due to the overwhelming amount of information generated. The researcher must engage in a process of focusing on some of the data and setting aside other pieces which may not be as relevant. This process allows for the development of a small number of themes or major categories representing the main findings within the research study (Cresswell, 2014). Data for this study was organized by research question and major themes relative to each question were addressed (Tables 2 and 3).

Research Question 1: How do middle school science teachers perceive the Next Generation Science Standards?

Shift 1: Science education must show real-world interconnections in science.

The information in Table 6 (Appendix G) shows teachers place a high value on the importance of three-dimensional learning. Three-dimensional learning reflects the integration of science and engineering practices, disciplinary core ideas, and cross-cutting concepts (Pratt, 2013). Eighty percent (80%) of teachers who took the survey strongly agreed science facilitated in the middle school classroom must simulate this interconnection as it is in the real world. One hundred percent (100%) of teachers either strongly agreed or agreed the NGSS would assist them in teaching students to apply scientific knowledge.

Participants were asked the following question in an interview setting: *Do you feel the demonstration of the interconnection in science is important for students at the middle school level? Explain why or why not.* There were three common themes which emerged from the interview responses (Table 2). The demonstration of the interconnections in science teaches problem-solving, promotes student engagement, and enhances science-reasoning skills. Problem-solving was mentioned most consistently among the participants.

When addressing the interconnections in science, Participant 1 noted "daily science opportunities and the chance to ignite that excitement about science for future design solutions is very important." Participant 3 asserted, "I think at the middle school level, they definitely should have that sense of interconnectedness that science isn't just about knowing things, it's about knowing how to do things, knowing how to model things and all the other applications." Participant 4 stated, "Students should be using all of these skills continuously to solve problems." Participant 7 said, "Maybe the kids are reading or taking notes or whatever, but they are doing something and actively participating in trying to figure something out every day." Participant 8 stated, "In my experience, students enjoy design, inquiry, and scientific learning."

Participants 2, 5, and 6 all expressed the importance of the interconnections in science, but did not explicitly address problem-solving, engagement, or science reasoning skills. Participant 2 believed this concept is a good idea in theory but is difficult to achieve at the middle school level. Participant 5 believed, "the primary focus is on a new style of teaching and learning before students can truly make meaningful connections the way that the NGSS would like." Participant 6 noted, "After some training, we understood about looking at patterns, cause and effect. We realized that this is not something to overlook."

Shift 2: The standards represent student outcomes.

Table 7 (Appendix G) indicates 93% of the science teachers surveyed either agreed or strongly agreed science standards should represent student outcomes as opposed to the curriculum. Eighty percent (80%) of teachers either agreed or strongly agreed the performance expectations detailed within the standards will help them create coherent instructional programs which will allow students to achieve the standards. The NGSS are meant to be used as a guide to assist teachers in the development of skills-based science curricula (Next Generation Science Standards Lead States, 2013). When asked if the performance expectations outlined in the standards would assist in preparing students for assessment, 80% of the participants agreed or strongly agreed. Performance expectations are designed to assist teachers with constructing assessments which assess students' mastery of skills (Willard, 2013).

Participants were asked the following question regarding assessment: *Have the NGSS had any impact on the way you assess your students or how you plan to assess them in the future*? *Explain.* The themes which emerged from interview responses included the following: a reduction in traditional testing methods, increased opportunities for formative assessment, and the use of performance-based assessment (Table 2).

Participant 1 stated, "I think performance-based assessments are definitely a thing of the future. I think there's a place for assessing students along the way and making sure they have those understandings." Participant 2 described recent lessons during which students would analyze data on their own and asserted, "The assessment will be them [students] crunching the numbers and looking at the patterns and that kind of thing." Participant 3 compared personal classroom testing practices between teaching in year 1 and now under the NGSS, "My tests that I made my first year was a lot of multiple choice. Since the release of the NGSS, I've gone away from that. I noticed myself with the NGSS referring back to a lot more rubric rating." Participant 4 noted how traditional practices of memorization no longer serve students well, "These standards are pushing them to apply the content. Many students are not achieving as high of grades as they did in the past due to just memorizing facts." Participant 5 mentioned an increased frequency in the use of laboratory-based practical classes and rubrics to assess science and engineering practices. Participant 6 noted the increased use of informal assessments. Participant 6 asserted, “I definitely changed all my tests. I think I'm not testing as often either.”

Participants 7 and 8 spoke about challenges in the area of assessment as it related to NGSS. Participant 7 noted, “a lot of them [teachers in the building] are still doing multiple choice tests, but they're starting to see more value in the performance assessments. Participant 7 also expressed the following: “Teachers were too overwhelmed. We can't assess content and keep track of where the kids are in these practices [science and engineering practices].” Participant 8 expressed the difficulty in assessing students on the standards because it requires a lot of time, “it is very time-consuming to assess NGSS because you need to assess their skills. Participant 8 also acknowledged challenges experienced in getting students to engage in skills-based assessments, “the kids who can memorize are really thrown off by those types of test. They do not like it and they beg for just a multiple-choice quiz.”

Shift 3: Science concepts should build progressively across grade levels.

Table 8 (Appendix G) shows science teacher participants responses to questions about learning progressions. All teacher participants agreed science concepts should build progressively from one grade to the next. All participants also agreed a teacher’s knowledge of the curriculum which is implemented in lower and higher grades is essential to the success of an NGSS-based curriculum. Thirteen participants agreed the NGSS would assist in creating a focused curriculum, while two participants neither agreed or disagreed. Eleven of the participants agreed the NGSS would assist in the development of a coherent curriculum, while four neither agreed or disagreed. Well-designed learning progressions can guide science teachers in assisting students to master core ideas in science (Next Generation Science Standards Lead States, 2013).

Participants were asked the following question during the interview: *Do you feel knowledge of curriculum which is implemented in grades below and above your own is essential to the success of an NGSS-based curriculum? Explain why or why not?* Two themes emerged from the responses to this interview question: Learning progressions can impact teaching; and learning and collaboration across grade levels helps guide curriculum development (Table 2).

Participant 1 spoke about the importance of collaboration across grade levels, "After rewriting our district's curriculum as a team, we now have a better understanding of what is being taught at each grade level." Participants 2, 3, 4, and 7 addressed the importance of students possessing appropriate background knowledge from prior grade levels. Participant 2 felt knowledge of learning progressions was essential, but felt it could be a disadvantage because the NGSS focuses on too little content, "They've taken out so much content, if we count on the fact that the kids know some basic things coming up, then it all falls apart." Participant 3 stated the following when referring to content which was not covered in a prior grade level: "It's really hard to make strides when you do not have the scaffolding from a lower grade level up to a middle school level." Participant 4 expressed concern about the district's elementary schools not devoting as much time to science as they should, and stated, "It will impact our teaching and learning." Participant 7 said, "kids definitely cannot do what NGSS wants them to do in middle school if they don't have science in elementary."

Participants 5, 6, and 8 discussed the value of teachers having an understanding of the curricula of other grade levels. Participant 5 addressed the importance of learning progressions in both lower and upper grades:

> It is integral to know what is being covered in lower grades so that we know what skills students have and are ready to expand as well as to recognize what has not been covered

> and needs to be introduced. In upper grades, it is important to know what expectations they will be facing so that we can provide them with a solid foundation.

When discussing how overwhelming it can be in trying to teach too much at one grade level, Participant 6 stated, “It makes you feel so much at ease that, you don't have to teach all.” Participant 8 mentioned, “I can't even imagine trying to get through the NGSS without a solid understanding of prior grades’ work.”

Shift 4: The standards must focus on deeper understanding and application of content.

Table 9 (Appendix G) shows teacher responses to survey questions about understandings in science and the application of content. Ninety-three percent (93%) of teachers from this sample agreed or strongly agreed the NGSS must focus on facilitating deeper understanding and greater application of content. Slightly fewer teachers (86%) agreed or strongly agreed the standards should focus on a small set of core ideas rather than facts and details relative to those ideas. Eighty-six percent (86%) of the science teachers surveyed also agreed or strongly agreed the standards will assist in guiding students to understand core principles and theoretical constructs as opposed to disconnected pieces of knowledge and isolated facts.

Participants were asked the following question regarding the level of student understanding of science concepts and the application of science: *In contrast to previous science education standards, the NGSS focuses on a small set of core ideas and deeper understanding and application of content. Do you feel this is appropriate for students at the middle school level?* The three main themes which emerged from the participants’ responses were: can promote student engagement, there must be a balance between the teaching of content and the application of skills, can be challenging to achieve in practice (Table 2).

Participants 1, 3, 4, 5, and 6 discussed how the focus on deeper understandings and the application of science content could lead to greater student engagement. Participant 1 made the following comment when discussing student engagement, “I think if you really want students to be engaged in science, they have to have the opportunity and the time to explore something that they’re really interested in and motivated by.” Participant 3 believed focusing on deeper understanding and content application allows students the opportunity to experiment and discover. Participant 3 asserted, “I think a lot of kids interpret science as just knowing a bunch of facts about things, but really it’s actually more of a verb than anything.” Participant 4 noted, when discussing how students learn, “their brains are growing and developing and they need a challenge”. Participant 5 said, “They are constantly seeking out connections on their own and seem to retain information the best when they can discover relationships.” Participant 6 reflected on practices and noted, “We're trying to spend more time on slowing down and just understanding what is the main thing the kids have to understand and not just raw memorization.”

Participants 2, 7, and 8 expressed concerns about the need for a balance between content and skills. When discussing the need for a balance between content and skills, Participant 2 noted, “There’s nothing wrong with being an inch deep and a mile wide sometimes too, because kids have a lot of different interests.” Participant 7 noted, “I do like that part of NGSS. I wonder at the end of the day are we going to say, not that a smattering of everything is good, but are the kids going to miss out on something.” Participant 8 stated, “Yes, in practice, but it's very difficult and almost impossible to achieve because there are too many obstacles at the middle school level.”

Shift 5: Science and engineering must be integrated in science education

Table 10 (Appendix G) shows science teachers’ responses to survey questions regarding the integration of science, technology, and engineering. Ninety-three percent (93%) of teachers agreed or strongly agreed science and engineering must be integrated in science education. More than 90% of teachers also agreed or strongly agreed the NGSS would assist in creating a curriculum which provides opportunities for students to deepen their understanding of science using engineering and technology. Ninety-three percent (93%) of teachers agreed or strongly agreed the NGSS would help empower students to use what they learn in science class in everyday life. Fewer teachers (80%) agreed the standards would help prepare students to address major world challenges.

Teachers were asked the following questions during the interviews: *How comfortable are you with incorporating technology into your science lessons?* And: *How comfortable are you with incorporating engineering practices into your science lessons?* The levels of comfort and additional thoughts expressed by each teacher were recorded. Teacher responses were organized into the following themes: promotes student engagement, teaches problem-solving, enhances science reasoning skills, engineering goes beyond building, can be difficult when students do not persevere (Table 2).

Participant 1 was comfortable incorporating engineering into science but expressed previous feelings of intimidation, “I was intimidated, but I think when you break down the process of the engineering design, the process to kids and to teachers, it's really not that intimidating.”

Participants 3, 4, and 5 discussed how incorporating engineering practices in science education can enhance students’ skills of scientific inquiry and reasoning. Participant 3 stated, “Engineering activities [work] through the cycle of asking a question, imagining a solution, planning, creating, testing and then improving, and then basically recycles itself again.”

Participant 4 said, “Even before NGSS, we always incorporated many of these practices into our daily lessons. We called them ‘inquiry skills’”. Participant 5 noted, “We often write three-dimensional objectives that tie together the science and engineering practices, cross-cutting concepts, and disciplinary core ideas.”

Participants 6, 7, and 8 acknowledged the open-ended nature of engineering design which engages students. Participant 6 stated “Engineering is not just building. It involves argument and finding evidence.” Participant 7 said, “I'm pretty comfortable with it. Just because there’s never really a right answer, I think you can’t mess it up.” Participant 8 used the word “medium” to describe their level of comfort with engineering, “I think it’s about medium as well. I enjoy it, the kids enjoy it.”

Participant 2 had prior career experience as a heating, ventilation, and air conditioning (HVAC) engineer. This participant expressed concerns about how challenging it is to facilitate engineering design activities in the science classroom. Participant 2 stated, “I'm comfortable with it. I used to be an HVAC design engineer. To be honest, we don't do it a ton because they give up so quickly.”

Shift 6: The standards must prepare students for college, careers, and responsible citizenship.

Table 11 (Appendix G) shows teacher responses to survey questions about student preparation for college, careers, and responsible citizenship. More than 90% of the participants agreed science standards should guide teachers in preparing students for college, careers, and responsible citizenship. More than 90% also believed the standards would assist in helping students realize science and science education are essential to the US’s ability to be a leading nation in innovation and future job creation.

Teachers were asked the following question during the interviews: *In your opinion, will the*

NGSS be adequate in helping middle school teachers prepare and guide middle school students on a path toward college, careers, and responsible citizenship? Explain why or why not. Three themes emerged: lack of preparation for college readiness, lack of preparation for responsible citizenship, and apparent challenges to accomplish goals (Table 2).

Participants 1, 6, and 7 expressed concerns about deficiencies in the ability of the standards to assist teachers in preparing students for high school or college. Participant 1 stated, “there's a lot of very traditional teaching still happening. I worry sometimes that we're adjusting a little bit faster at the K through eighth level than the high school.” Participant 6 noted the following while expressing concern about the lack of content in the NGSS: “I feel like I'm constantly looking for resources.” Participant 7 stated, “They [the standards] prepare you to be a smart consumer or responsible citizen. As far as the college readiness goes, the content is lacking a little bit.”

Participant 3 agreed the standards would assist in preparing students for college and careers, but did not see a connection with responsible citizenship. They stated, “As for the responsible citizenship, I'm not exactly sure on that. I can't recall anything written in the NGSS that is to better society.”

Participants 2, 5, and 8 believed the standards have the potential to assist teachers in preparing students for college, careers, and responsible citizenship, but acknowledged challenges associated with this task. Participant 2 mentioned the NGSS harbor a false premise that “Everybody has to go to college.” Participant 2 asserted, “When they say *career*, what teacher is actually thinking of plumber or mechanic or things like that?”

Participant 5 expressed in time, the standards will assist teachers more with preparing students for college, careers, and responsible citizenship, “but at the current moment it is a momentous task to accomplish." Participant 8 stated, "I think they could be, there's just so much to overcome."

Participant 4 was the most positive regarding the ability of the standards to prepare students for college, careers, and responsible citizenship. Participant 4 stated, "The ability to think outside the box to solve problems, reading and research and writing will help them in any job they may encounter."

Shift 7: The standards must coordinate with Common Core Math and Language Arts Standards.

Table 12 (Appendix G) shows teacher responses to survey questions about the alignment of the NGSS to the *Common Core Standards*. Seventy-three percent (73%) of the participants agreed or strongly agreed there must be coordination between the NGSS and the *Common Core Math and Language Arts Standards*. A small percentage of teachers (7%) disagreed with this statement. More than 90% of teachers agreed the NGSS would assist in making science a consistent part of students' comprehensive education.

Teacher participants were asked the following question during the interviews: *In your opinion, is it important for the NGSS to coordinate with Common Core Math and Language Arts Standards? Why or why not?* The following themes emerged from the interview responses: creates similar expectations between classes, facilitates improved performance in all subject areas, students learn to communicate science knowledge, coordination with Common Core is good but should not be a priority (Table 2).

Participants 7 and 8 acknowledged coordination between the standards creates similar expectations among classes for students. Participant 7 stated, "I think if they don't coordinate, it's too much. Participant 8 said, "I think it's helpful for the students because it's less confusing, and it helps them get better scores in math and English Language Arts (ELA)."

Participants 3 and 4 acknowledged coordination would help improve scores. Participant 3 agreed the NGSS should coordinate with the *Common Core Math and Language Arts Standards*, stating, “Everything that we’re doing, we’re doing to improve the kids’ reading and math abilities.” Participant 4 stated, “These skills should be worked on in all three subjects so the students can improve their growth in all areas and be well rounded.”

Participants 2 and 5 did not feel the coordination between the two sets of standards was a priority. Participant 2 expressed concern regarding how the sustained focus on language arts and math has produced limited results. Participant 2 stated, “All the attention, all the efforts put in math and language and what has it gotten us? I don't really think it's [NGSS and Common Core alignment] terribly an important thing.” Participant 5 agreed there should be alignment between the two sets of standards, but stated, “I do not see this as a huge priority or benefit in teaching right now.”

Participant 6 expressed there should be alignment between *Common Core* and the NGSS, and acknowledged the need to coordinate more with math and language arts teachers in the school building. Participant 1 noted, “they have to be able to communicate about science efficiently.”

Table 3

Emergent Themes Related to the Research Question 3

Research Question	Emergent Themes
Question 2: **What resources and support systems do teachers report as being beneficial in the implementation of the NGSS?**	- sustained, relevant professional development - lesson sharing/collaboration with colleagues - resources aligned with the new standards - flexible, learner-centered classroom
Question 3: **What do middle school science teachers report as being challenges or barriers to implementing the NGSS?**	- confusing organization of the standards - varying interpretations of the standards - will take time to implement properly - meeting personal expectations as a science teacher

Research Question 2: What resources and support systems do teachers report as being beneficial in the implementation of the NGSS?

Teacher participants were asked to identify factors which have served to support the implementation of the NGSS. The following themes emerged after an examination of teacher responses: sustained, relevant professional development; lesson sharing/collaboration with colleagues; resources aligned with the new standards; and flexible, learner-centered classroom (Table 3).

Participants 2, 3, and 8 discussed professional development experiences which had been most supportive during the NGSS implementation process. Participant 2 referenced a long-term professional development opportunity as being helpful:

> The type of long-term training and time like we're getting at Fermilab is most helpful. Otherwise, it is too much, without enough time to really figure it out and try to create a curriculum that is worth doing.

Participant 3 stated, "Profession development which ranges from a whole bunch of different things that I attended has really helped me out." Participant 8 mentioned different types of professional development opportunities as being most helpful: “I have attended many NGSS seminars, round-table discussions and in-service opportunities.”

Participants 1, 7, and 8 discussed how the sharing of lessons and collaboration with colleagues had been most helpful. Participant 1 stated, “online teacher share sites have been helpful.” Participant 7 said, “I definitely think that it’s been helpful to continuously talk about it in a lot of different ways.” Participant 8 said, “Our science department meets frequently to share successes and struggles.”

Participants 1, 2, and 4 mentioned the availability of aligned resources as being assistive during the implementation of the standards. Participant 1 stated, “the new textbook (aligned with the new standards) has been helpful.” Participant 2 referenced, “Bozeman Science videos in which the main character breaks down the science and engineering practices.” Participant 4 noted, “We purchased Stemscopes as a resource which has been helpful. We do not do everything, but we adapt, modify, etc. as we see fit.”

Participants 5 and 6 noted having the opportunity to explore and be open has been most helpful. Participant 5 stated, “The most supportive thing has been the willingness for us to explore and try new things.” Participant 6 said, “I think that the greatest thing is that I feel, through this process, that I am on the side of my class.”

Research Question 3: What do middle school science teachers report as being challenges or barriers to implementing the NGSS?

Teacher participants were asked to discuss factors which have served as challenges or barriers to the implementation of the NGSS. The following themes were discovered after coding the interview responses: confusion due to the organization of the standards document, varying interpretations of the standards, will take time to implement properly, meeting personal expectations as a science teacher (Table 3).

Participants 2 and 8 addressed the complexity in the way the standards document is organized. Participant 2 stated, “I think the way all the documents are set up, it’s just overwhelming.” Participant 8 reported confusion was experienced by colleagues when discussing the standards: “We were all a little confused in determining which one was actually the standard and which was just a clarification of a standard.”

Participants 3, 4 and 5 noted the ways in which the NGSS are interpreted could serve as a barrier. Participant 3 stated, “The NGSS pushes for technology, but they’re not specific enough on what that technology actually is.” Participant 4 noted, “The only barrier is that NGSS only has middle school standards.” This participant expressed concern with the idea of having to divide the middle school standards as a department. Participant 5 stated, “Teachers can have different interpretations of what NGSS should look like in the classroom.”

Participants 1, 4, 5, 6, and 7 referred to time as a barrier which has had the most significant impact. Participant 1 discussed the difficulty in maintaining continuity with NGSS-related lessons and stated, “The biggest challenge is starting and stopping a 42-minute period.” Participant 4 expressed, “there is a lot there and not a whole lot of time, so we do our best.” Participant 5 stated, “The biggest challenge is time. Participant 6 attributed the need for extra time to the fact that “we have had to revamp things.” Participant 7 stated, “A barrier has been that I’ve tried to do too much in too little time. When you’re overwhelmed, you might want to make the changes but you just can’t.” Participant 1 noted, “Meeting our own expectations for common assessments, making sure that students can hit those marks when we establish a timeline, kind of restricts us a little bit to meeting the true NGSS model.”

Teacher Lessons

Six of the 15 teacher participants submitted recent science lessons as extant data sources. The lessons were assessed using the EQuiP Rubric. The EQuiP rubric is designed to assess science lessons and science units using three categories: alignment to the three-dimensional learning design, instructional supports, and monitoring student progress (NGSS, 2014). Each of these categories is broken down further into several criteria which NGSS lessons and units should aim to meet. All examples submitted by the six teacher participants were individual lessons which had been facilitated in the context of an NGSS classroom. The researcher applied the portions of the EQuiP rubric appropriate for the evaluation of science lessons. Table 4 summarizes the researcher's analysis of the lesson samples using the rubric. A checkmark next to a criterion indicates adequate evidence was found in the lesson sample to meet the expectations of the EQuiP rubric. A blank box indicates little or no evidence for a given criterion was found in the lesson sample.

Participant 1: Engineering Design - MS-ETS1-4

Participant 1 provided an example of a lesson which had been used in an eighth grade science classroom. The lesson addressed the following performance expectation: *Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.* The goal of the lesson was to create a working hot air balloon which demonstrated an understanding of the following: How a hot air balloon flies, how heat affects the behavior of molecules, and how heat affects molecular density. The students were organized into teams and asked to research, plan, and draw designs. The students were also provided with a variety of materials from which to choose and a rubric which explained the criteria for the assignment.

Participant 2: Heredity, Inheritance, and Variation of Traits - MS-LS3-2

Participant 2 provided an example of a genetics lesson which was used in an eighth grade

Table 4

Analysis of Teacher Lesson Samples using the EQuiP Rubric

		Participant ID					
		P1	**P2**	**P3**	**P4**	**P5**	**P6**
		NGSS Standard					
		MS-ETS1-4	**MS-LS3-2**	**MS-ETS1-4**	**MS-LS1-1**	**MS-PS2-2**	**MS-ESS2-1**
EQuiP Category	**Lesson Criteria**						
3D Design	Explaining Phenomena/Designing Solutions	✓	✓	✓	✓	✓	✓
	Three Dimensions	✓	✓	✓	✓	✓	✓
	Integration of Dimensions	✓	✓	✓	✓	✓	✓
Instructional Supports	Relevance and Authenticity	✓	✓	✓		✓	✓
	Student Ideas		✓	✓			
	Building Progressions		✓				✓
	Scientific Accuracy	✓	✓	✓	✓	✓	✓
	Differentiated Instruction					✓	
Monitoring Student Progress	Monitoring 3D Student Performance	✓	✓	✓	✓	✓	✓
	Formative Assessment		✓	✓			
	Scoring Guidance	✓	✓				
	Unbiased Task/Items	✓	✓	✓	✓	✓	✓

classroom. The lesson addressed the following performance expectation: *Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.*

The unit is a series of virtual lessons produced by the Concord Consortium which engages students in a game-like learning scenario. The lessons used by Participant 2 follow the

5E instructional model and allow students to learn about heredity and genetics by breeding virtual dragons. The students were allowed to create questions of relative interest and design virtual experiments to explore answers to these questions. The lesson included opportunities for teachers to facilitate discussions about relevant vocabulary and implement formative assessments.

Participant 3: Engineering Design - MS-ETS1-4

Participant 3 shared an engineering design lesson which involved the creation of a crane: The lesson addressed the following performance expectation: *Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved*. The students were introduced to the engineering design process and were provided with an initial problem: "How can I engineer a construction crane to lift a load of two textbooks?" The parts of a crane are introduced as well as the criteria and constraints of the assignment. Students were divided into teams and asked to plan, draw sketches, and determine what materials would be needed to construct each part of the crane. Students were instructed to build the crane and collect data on the crane's performance. A second, more complex problem was then introduced: "How can I engineer a construction crane to lift a load of five textbooks?" The students followed similar procedures as before but must redesign the original crane to meet the new challenge. The final portion of the lesson required students to form conclusions about the device and the experience using data and information collected throughout the process.

Participant 4: From Molecules to Organisms – Structure and Processes - MS-LS1-1

Participant 4 submitted a lesson in which students experiment with energy drinks and *Daphnia* water fleas. This lesson addressed the following performance expectation: *Conduct an investigation to provide evidence that living thing are made of cells; either one cell or many* *different numbers and types of cells.* The students were provided with a lab sheet with the following investigative question: "What are the effects of energy drinks on *Daphnia*?" They designed an experiment to test the effects of different energy drinks on *Daphnia* such as by measuring their heart rate. Students were asked to make a hypothesis using the key words "if," "then," and "because." The lesson further required students to identify independent, dependent, and controlled variables and to design an experimental procedure for investigating the initial question. The students were guided to collect qualitative and quantitative data from the experiments. The students constructed a conclusion in which the collected data was organized into evidence to support a claim about the investigating question.

Participant 5: Motion and Stability – Forces and Interactions - MS-PS2-2

Participant 5 shared an investigation which involved calculating the speed of objects. This lesson addressed the following performance expectation: *Plan an investigation to provide evidence that the change in an objects motion depends on the sum of the forces on the object and the mass of the object.* The goal of the investigation was to calculate speed according to distance traveled and time elapsed. Participant 5 provided three versions of this investigation with various levels of difficulty. Version 3 was the most complex and open-ended and was the one evaluated for this study. The lesson poses the following question to students: "How can we calculate the speed of a moving object?" Students were directed to use a small set of materials to answer the lab question. Students collected and graphed qualitative data. The students must made conclusions according to claims, evidence from data collection, and reasoning. Students were asked to make connections to their own lives and to other scientific and non-scientific concepts. Extensions were also provided to allow students the opportunity to investigate further. The first and second versions of this investigation followed a similar format but were more guided.

Participant 6: Earth's Systems - MS-ESS2-1

Participant 6 shared a lesson in which students investigate four major Earth systems: the atmosphere, biosphere, geosphere, and hydrosphere. The lesson addressed the following performance expectation: *Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.* The goal of the lesson was for students to discover and model ways in which the four spheres are connected. The students read the history of knowledge of each system to gather and learn background information. Students then conducted laboratory-based investigations to learn more about interactions between the systems. One example of a laboratory class is called the *Dust Bowl*. This investigation assisted students in learning about the effects of weathering and the impacts it has on Earth's systems. Students attempted to answer the question: "Why is there so much dirt in the air after a farmer harvests a crop?" Students were introduced to materials and guided through a prescribed procedure. Directives were given which asked students to record data. A discussion followed the lab procedure. Graphic organizers were used throughout the lesson to help students organize the information collected. Participant 6 said, "We spend over a month connecting the spheres, with them [students] each choosing an Earth system interaction such as floods, droughts, mudslides, meteor impacts, blooming of phytoplankton, or invasive species." The students used all of the data and information collected to inform the creation of a large model which showed connections between the spheres. Students' models were presented through Google slide shows.

Reliability and Validity

The researcher attempted to ensure the credibility and reliability of the study by collecting data and information from various sources. Triangulating a qualitative study requires the use of data obtained via several methods (Mayer, 2015). The researcher collected data for this study from surveys, interviews, and teacher lesson samples. The constant comparative methods used in the grounded theory methodology worked to ensure the reliability of the study. This required newly-collected data be compared to existing data. The researcher continuously compared data within and between interviews during the processes of data collection and analysis.

The researcher used methods of data collection and analysis appropriate for this study to ensure its credibility. Interviews were recorded using an audio recorder. The recordings were transcribed by the researcher and checked for accuracy. Lesson plans were reviewed and evaluated twice with the EQuiP rubric to ensure all relevant evidence was captured.

Chapter Summary

This chapter presents the findings of this qualitative grounded theory research study. Data for this study was organized according to the research questions and the major themes which emerged from the investigation of each question. Data from the *Middle Level Science Teacher Perception Survey* was collected through Survey Monkey and organized into charts. The first chart illustrates where science teachers placed themselves according to the NGSS Implementation Pathway Model. Subsequent charts illustrated science teachers' responses to questions related to the seven conceptual shifts expected in science education as a result of the NGSS. Qualitative data from the teacher interviews were presented in the form of direct quotations which represented teachers' genuine responses and perceptions of the NGSS. The researcher used processes of open coding, axial coding, and selective coding to draw relevant themes from the interview data. Six of the participants submitted lesson plans, which were evaluated using the EQuiP rubric. The EQuiP rubric was designed to assess science lessons and science units using three categories: alignment to the three-dimensional learning design, instructional supports, and monitoring student progress (NGSS, 2014). A summary table was created to present the analysis of teacher lesson samples using the EQuiP rubric.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this grounded theory study was to better understand how middle-level science teachers viewed the Next Generation Science Standards (NGSS). The study also sought to understand teachers' experiences with NGSS implementation in middle school classrooms. Teachers' perceptions of educational standards are known to influence teaching practices (Savasci & Berlin, 2012). Examining how teachers perceived the NGSS allowed the researcher to identify teachers' ideas and beliefs regarding the implementation of the NGSS. Few studies have been identified which focus specifically on middle school science teacher perceptions of the NGSS. This study helps to address the need for additional research in this area. The findings from this study supplement similar existing studies and ones currently in progress, as research in this area is still relatively new. Fifteen middle-level science teachers within and around DuPage County, Illinois, participated in this study. The participants completed surveys, interviews, and submitted samples of lessons which were recently implemented in the classroom. A grounded theory methodology was used to analyze the data. Data were coded and organized according to the research questions, and themes related to each question were identified. This chapter includes a summary, discussion, and the researcher's interpretations of the findings, followed by the study's conclusions, limitations, the researcher's recommendations, and leadership implications.

Findings, Interpretations, Conclusions

The first stage of this study involved middle-level science teachers completing the *Middle Level Science Teacher Perception Survey (MLSTPS)* (Appendix D) developed for this study. This survey was composed using the seven conceptual shifts expected in science education as a guide. Survey Monkey was used to administer the survey to teacher participants.

Fifteen study participants completed the MLSTPS. Eight of the 15 participants agreed to participate in an interview. Six of the 8 teachers submitted examples of lessons recently implemented in the science classroom.

Themes were identified relevant to each research question. The researcher used Research Question 1 to identify teachers' perceptions of each of the conceptual shifts expected in NGSS-based science education. The greatest number of themes emerged from Research Question 1, which examined teachers' perceptions of each of the seven conceptual shifts. Research Question 2 was used to investigate what was considered to be most assistive during the standards implementation process. Question 3 assessed factors teachers identified as being challenges or barriers to the implementation process.

Research Question 1: How do middle school science teachers perceive the Next Generation Science Standards?

Science education must show real-world interconnections in science.

The first section of the *MLSTPS* was comprised of statements which addressed the first conceptual shift, *interconnections in science*. The statements in this section addressed curriculum construction, the application of scientific knowledge, and the relationship between scientific content, the practices of scientific inquiry, and engineering design. All 15 participants (100%) strongly agreed or agreed with each statement, except in the area of curriculum construction. Two teachers (13%) responded neutrally to the following statement: *The NGSS will help me construct a curriculum that is deeply contextual*. Although two teachers did not agree or disagree the NGSS will assist in constructing a deeply contextual curriculum, the remaining responses are consistent with the assertions of Krajicik (2015). Krajicik noted teaching science in a way which demonstrates the relationships between science content, science and engineering practices, and crosscutting concepts, will help students acquire a deeper understanding of science. This method of teaching also guides students in the development of skills such as problem-solving and critical thinking. It also encourages the application of scientific knowledge to situations outside of the classroom.

Themes which emerged from the interview responses related to the interconnections in science were the following: teaches problem-solving, promotes student engagement, and enhances science-reasoning skills. Problem-solving was the most common theme which emerged. Curricula in which students are engaged provide opportunities for students to problem-solve and use scientific reasoning skills. This allows students to make connections between the classroom and the outside world. Having the opportunity to participate in meaningful and relevant science is a goal of science education (Trauth-Nare, 2016).

A review of the lesson samples submitted by the six science teachers indicated the conceptual shift, *interconnections in science,* is being acknowledged and represented in current lesson designs. The six lesson samples contained core content from the areas of life science, physical science, and Earth science. The evidence from the lessons suggested teachers made attempts to guide students toward developing and using specific elements of the science and engineering practices (SEP), disciplinary core ideas (DCI), and crosscutting concepts (CCC). Table 5 provides a summary of the three dimensional elements found in each lesson.

Table 5

Three-dimensional Elements Discovered in Science Teacher Lessons

Science Lesson	SEPs Addressed	DCIs Addressed	CCC Addressed
Participant 1: *Engineering Design - MS-ETS1-4*	- Planning and Carrying Out Investigations - Constructing Explanations / Design Solutions	- Matter and its Interactions	- Cause and Effect: Mechanism and Explanation
Participant 2: *Heredity, Inheritance, and Variation of Traits - MS-LS3-2*	- Asking Questions and Defining Problems - Planning and Carrying Out Investigations - Analyzing and Interpreting Data	- Heredity: Inheritance and Variation of Traits	- Patterns - Cause and Effect: Mechanism and Explanation
Participant 3: *Engineering Design - MS-ETS1-4*	- Asking Questions and Defining Problems -Planning and Carrying Out Investigations - Analyzing and Interpreting Data - Constructing Explanations / Design Solutions	- Motion and Stability; Forces and Interactions	- Cause and Effect: Mechanism and Explanation
Participant 4: *From Molecules to Organisms – Structure and Processes - MS-LS1-1*	- Planning and Carrying Out Investigations - Analyzing and Interpreting Data - Constructing Explanations / Design Solutions	- From Molecules to Organisms: Structures and Processes	- Cause and Effect: Mechanism and Explanation
Participant 5: *Motion and Stability – Forces and Interactions* - MS-PS2-2	- Planning and Carrying Out Investigations - Analyzing and Interpreting Data - Constructing Explanations / Design Solutions	- Motion and Stability; Forces and Interactions	- Cause and Effect: Mechanism and Explanation
Participant 6: *Earth's Systems - MS-ESS2-1*	- Asking Questions and Defining Problems - Analyzing and Interpreting Data - Developing and Using Models - Constructing Explanations / Design Solutions - Obtaining, Evaluating, and Communicating Information	- Earth's Systems	- Cause and Effect: Mechanism and Explanation - System and System Models

These findings are consistent with what was mentioned in the literature review presented in Chapter 2. The Framework for K-12 science education states the following: "K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world" (National Research Council, 2012). The integration of disciplinary core ideas, cross-cutting concepts, and science and engineering practices will help students develop skills of problem-solving and critical thinking, and promote a deeper understanding of scientific content. Students will be able to better apply this content to personal situations of interest and real-world problems.

The standards represent student outcomes.

The focus of this section of the MLSTPS was on student outcomes. Teachers responded to statements which addressed performance expectations and assessment. Twelve participants (80%) believed the performance expectations described in the NGSS would assist in preparing students for assessments. Performance expectations describe what students must do in order to demonstrate mastery (Willard, 2013). The performance expectations are intended to assist teachers in the development of assessments to test students' mastery of content and skills (Next Generation Science Standards Lead States, 2013). Previous state and national standards did not include performance expectations such as those illustrated by the NGSS. Former standards were often presented in what Marshall (2015) calls a "one-to-one ratio between the standard and the objective." Treating student learning as a checklist did not require the kind of ongoing exploration and investigative techniques required by the NGSS. Themes which emerged from responses to the interview question about performance expectations and assessment included the following: increased opportunities for formative assessment, a reduction in traditional testing methods, and the use of performance-based assessment.

Formative assessment is a classroom assessment practice used to monitor student achievement and give teachers the feedback necessary to adjust instructional practices to improve student learning. Formative assessment can assist teachers in promoting a deeper understanding of concepts taught in class (Cornelius, 2014). Using formative assessments consistently can assist teachers in accomplishing this task. Clearly communicating performance expectations to students will also result in improved achievement. This allows students to become more self-directed learners. Teaching practices involving formative instructional processes allow teachers to gain insights by analyzing and reflecting on student performance (Klute, Apthorp, Harlacher, & Reale, 2017).

During the interviews, participants spoke about the need to rely more on performance-based assessments instead of traditional testing methods to assess students' understanding of concepts. Performance-based assessments are those which measure students' ability to apply the content and skills learned from a lesson or unit (Galvin & Coronado, 2014). Several teachers mentioned how methods of testing in the classroom have changed. One teacher noted how there has been a shift from the use of multiple-choice assessments to performance assessments requiring students to be evaluated using a rubric.

A review of the lesson samples submitted by the participants showed several could be used as performance assessments or lessons leading to performance-based unit assessment. Two of the six lessons included direct evidence of formative assessment opportunities. Participant 2's lesson (*Geniverse*) included opportunities for the teacher to track students' progress through levels of the lesson. Participant 3's lesson (Creating a Construction Crane) allows students to create and test a crane. Students then engaged in a second iteration of building and testing in order to improve the crane's performance. This provides opportunities for teachers to see students' progress and make changes to instructional practices to maximize learning. Students also gain valuable information which can be used to improve performance. Kim, VanTassel-Baska, Bracken, Feng, & Stambaugh (2014) asserted performance-based assessments are effective in assessing science literacy, understanding of content, scientific reasoning, and higher level thinking.

Science concepts should build progressively across grade levels.

Successful implementation of a curriculum which builds coherently across grades levels implies science teachers must give attention to student learning progressions. Learning progressions are conceptual pathways along which students progress when acquiring the content and skills needed to master a subject (Pruitt, 2014). All 15 teachers believed science concepts must build progressively across grade levels. All 15 teachers also believed teachers should have some knowledge of the curricula covered in adjacent grade levels. Such knowledge empowers teachers to prepare content and skill-based materials appropriate for students. An analysis of the interview responses related to learning progressions showed results were mostly consistent with data from the survey. Two themes emerged from the interviews: learning progressions can impact teaching and learning, and collaboration across grade levels helps guide curriculum development.

Having an understanding of learning progressions in a subject assists teachers in identifying the strategies and methods effective in guiding students toward achieving academic learning goals. Learning progressions also guide teachers when assigning group and individual tasks to students and in the development of formative and summative assessments. Teachers have many opportunities to plan appropriate lessons and assessments when learning progressions are well conceptualized and understood. This allows teachers to focus more on the learning goals rather than what students will do. Effective planning for teaching and learning first calls for the identification of the learning goal. Lessons and experiences designed to meet the learning goal are then connected to the goal and planned as appropriate (Achieve, 2015)

Collaboration across grade levels allows teachers to be able to articulate what content and skills are actually being taught within each grade. This information can be used by science teachers when planning appropriate learning activities to help students meet specific learning goals. Collaboration among teachers was referred to earlier, in Chapter 2. Passmore (2015) noted during an NGSS professional development session, science teachers expressed collaboration among teacher colleagues was an important dynamic which should be supported by administrative leaders. Collaboration among teachers allows for the creation of a focused and coherent curriculum (Next Generation Science Standards Lead States, 2013). This means teachers will be in a position to create curricula for students which do not cover the same content from year to year but, instead, provide progressive content allowing students to engage with more complex scientific concepts at higher grade levels.

Although it is evident from the survey data and interview responses teachers recognize the value in planning instruction around student learning progressions, there was no direct evidence of this in the lesson documents submitted by teachers. The EQuiP rubric calls for science lessons to explicitly identify the prior student learning expected for all three dimensions and to clearly explain how prior learning will be built upon. While the prior content and skills needed to complete each of the lessons submitted by the participants in this study can be inferred, this information is not directly stated in the lesson introductions.

The standards must focus on deeper understanding and application of content.

Most teachers responded with “strongly agree” or “agree” to statements regarding the understanding and application of science concepts. Fourteen (93%) teachers agreed science standards must focus on deeper understanding and the application of science content. In order to successfully explore science content more deeply, it is necessary to limit the number of concepts students are being asked to learn. Thirteen teachers (87%) agreed science standards should focus on a small set of core ideas instead of a large number of facts and details. Core ideas serve as a foundation upon which additional knowledge can be constructed (Next Generation Science Standards Lead States, 2013). Thirteen teachers agree the NGSS can assist in teaching students to learn and understand core concepts instead of disconnected pieces of knowledge and isolated facts. A deeper understanding of science develops when science teachers make a shift from having students learn sets of facts to engaging in scenarios where students collect and use evidence to construct explanations of the natural world (Bybee, 2014b).

Three themes emerged from the interview responses when participants were asked to respond to statements about understanding and application of science content. Based on the participants’ responses, there should be a balance between the teaching of content and skills. Teaching science in a way which promotes a deeper understanding and encourages the application of concepts can improve student engagement. Teachers also noted this method of teaching can be challenging to achieve in practice.

The NGSS were designed to assist teachers in promoting a deeper understanding of content and by engaging students in practices to allow the application of science concepts. Trauth-Nare (2016) noted the application of scientific knowledge to socially relevant situations is what contributes to one’s scientific literacy. Through Next Generation Science, teachers have opportunities to spend more time in the classroom developing understandings of core ideas. Students might develop questions of interest, design laboratory investigation procedures, gather evidence, and construct models. Students may also engage in investigations on broad science issues rather than simple lessons in individual concepts (Henderson, 2013). This method allows for a more student-centered learning environment in which students are engaged and self-directed.

Several of the lesson samples submitted by teachers in this study reflect the teachers' acknowledgement of this conceptual shift. Lessons such as participant 5's *Calculating Speed Lab* requires students to make connections to personal experiences outside of the classroom. Students must have a deep understanding of the physics inherent within this activity in order to appropriately make relevant connections. Lessons such as participant 1's *Hot Air Balloon Design Challenge* and participant 5's *Creating a Construction Crane Engineering Challenge* require a deep understanding of science concepts such as the Kinetic Molecular Theory of Matter and physical forces. Students must apply this knowledge appropriately in order to meet the challenges set forth in each activity. Problem-based and project-based curricula are effective in assisting student with knowledge acquisition, knowledge application, and science investigation skills (Kim et al., 2014). The lesson sample submitted by Participant 6, *Earth's Interactions*, involved numerous opportunities for students to investigate and acquire an in-depth understanding of the 4 major Earth Systems. Students were required to use what has been learned to inform the construction of a model showing connections between the major systems. Developing and using models is one of the 8 NGSS science and engineering practices. As mentioned in chapter 2, middle and high school teachers who utilized methods of modeling instruction felt more comfortable and prepared to implement the NGSS (Haag & Megowan, 2015).

Science and engineering must be integrated in science education

Fourteen (93%) of the 15 participants agreed engineering topics must be integrated into science education. Fourteen (93%) also agreed the NGSS will assist in creating a curriculum which provides students with opportunities to use engineering and technology to deepen understandings in science. *A framework for K–12 science education: Practice, crosscutting concepts, and core ideas* noted students should have a deep understanding of science and engineering. This allows students to be in a better position to make decisions and solve problems (National Research Council, 2012). Themes which emerged from the interview responses related to the integration of science and engineering included the following: promotes engagement; teaches problem-solving and engineering; enhances science-reasoning skills; and challenges students' level of perseverance.

It is important for students to see the connection between science and engineering as this understanding places students in a position to make informed decisions in everyday life (Moore et al., 2015). Making the connection between science and engineering stronger also assist the U. S. in remaining competitive in the global economy. Incorporating engineering activities into science gives students an opportunity to become engaged in science-related problems of interest (Bartholomew, 2015).

Student engagement is critical as it enhances students' ability to learn and achieve in science (Tas, 2016). Students become more engaged in science when presented with opportunities to creatively solve problems of interest. Moore et al (2015) noted two benefits of incorporating engineering into science, one being improved performance and achievement in both science and mathematics. The second benefit is increased student interest in STEM-related subjects and careers.

Project-based and problem-based learning activities provide students with opportunities to engaging in problem-solving endeavors. The engineering process involves a systematic iterative process in which engineers repeatedly design, build, and test an object until it reaches its optimal performance (Boesdorfer & Greenhalgh, 2014). Students develop skills of problem solving, critical thinking, and science reasoning when this process is replicated in the science classroom. Learning opportunities such as these improve students' ability to transfer the knowledge and skills which have been learned in class to real life situations (Dixon & Brown, 2012).

Two of the lessons submitted by teachers in this study show evidence of the integration of science and engineering. Lessons such as the *Hot Air Balloon Design Challenge* and *Creating a Construction Crane Engineering Challenge* require students to engage in an iterative process which involves building, testing, data analysis and design improvement. Students repeat this process until the design challenge is met. Design processes are central to the practice of engineering and are represented heavily in these design challenge lessons. Planning and evaluating solutions are key components of the engineering design process (Moore et al., 2015). These skills are evident in these lessons.

The standards must prepare students for college, careers, and responsible citizenship

The large majority of teachers in this study responded positively to questions related to the potential of the NGSS to prepare students for college, careers, and responsible citizenship. Thirteen (87%) teachers agreed the NGSS will assist in teaching students science plays a central role in the lives of Americans. The same percentage of teachers responded positively regarding the ability of the standards to help students understand science education is essential to the ability of the U.S. to continue to innovate, lead, and create future jobs.

Although teachers' responses to the survey questions about college, careers, and responsible citizenship were mostly positive, the semi-structured interviews allowed teachers to be more open about this topic. The themes which emerged from the interview data suggested teachers still had some concerns regarding the impact of the NGSS in this area. The following themes emerged: lack of preparation for college readiness, lack of preparation for responsible citizenship, apparent challenges to accomplish goals.

Teachers discussed the lack of extensive science content in the NGSS could present challenges when preparing students for college. The way science is facilitated in the K-12 classroom setting is changing to become less teacher centered and more student centered. While there is a greater focus on science and engineering practices and problem solving at this level, there is still a major focus on content in college learning environments. This is a great concern for teachers who feel students will be placed at a disadvantage due to deficiencies in certain content areas in science.

Sixty five percent (65%) of all jobs will require a form of postsecondary education and training by the year 2020. This number increases to 95% for STEM related positions. The ability of the U.S. to remain a competitive leader in the global economy is dependent upon whether or not students receive a K-12 education in science which emphasizes the preparation for college, careers, and responsible citizenship (Lead States, 2013). Previous standards documents such as the *National Science Education Standards* (NRC) and *Benchmarks for Science Literacy* (AAAS) served to help create a more scientifically literate population over the last two decades. Many advances in science and technology have occurred since the inception of these documents.

A large number of high school graduates are not prepared to meet the challenges of college and careers (Rothman, 2012a). A focus on college and career readiness is important because 40% of new college students enroll in remedial courses to compensate for inadequate skills needed to do well in regular college courses. Employers of high school graduates also note the lack of common skills needed to be successful (U. S. Department of Education, 2010). Educational standards which guide science curriculum must reflect these advances in science and technology in the classroom setting. The NGSS have been designed to guide teachers in assisting students to develop the knowledge and skills needed to become well-informed citizens, to be prepared for post secondary college and career endeavors, and to appreciate the role of science in everyday life.

The lessons submitted by teachers do not explicitly address college, careers, and responsible citizenship, but contain elements which are essential in guiding students to become critical thinkers and problem solvers. Critical thinking involves the use of strategies and skills which will lead to a favorable outcome. This kind of thinking is directed, reasoned, and purposeful. Individuals are engaged in critical thinking when making personal decisions and decisions which affect the lives of others. Several of the lessons submitted by teachers provide students with the opportunity to problem solve. This requires students to engage in a level of critical thinking and evaluate the potential outcomes and effects of the choices made (Halpern, 2014). Critical thinking and problem solving are both essential for success in college level academics and career endeavors.

The standards must coordinate with Common Core Math and Language Arts Standards.

Although most teachers agreed with statements regarding the coordination of the NGSS with Common Core State Standards, fewer teachers indicated strong agreement with these statements. Twenty percent (20%) of teachers strongly agree the NGSS must coordinate with Common Core Math and Language Arts Standards. Seventy-three (73%) agreed overall. A slightly higher percentage (27%) felt strongly about the ability of the NGSS to assist teachers in providing equitable access to learning standards for all students. Seventy-three (73%) agreed overall. Forty percent (40%) of teachers strongly agree the standards will assist in making science a part of students' comprehensive education. Ninety three percent (93%) of teachers agreed overall.

Themes which emerged from the semi-structured interviews showed teachers felt positively about the coordination of the NGSS with the Common Core State Standards. The emergent themes included the following: coordination creates similar expectations between classes, students learn to communicate science knowledge, and coordination between the standards should be evident, but not a priority.

The Common Core State Standards were developed in 2009 and unveiled in 2010 in response to national concerns about the level of college and career readiness among U.S. high school students. The Common Core State Standards was an effort to standardize public education by having states adopt similar math and language arts standards across the nation and submit to state or national testing on the standards (Pense et al., 2015).

The NGSS and the Common Core State Standards for math and language arts share grade by grade alignment. This means concepts students learn in science are supported throughout the entire curriculum. The NGSS document provides specific connections to Common Core State Standards for each NGSS performance expectation (Bybee, 2014b). This provides teachers with the necessary guidance to create lessons which are comprehensive and cross curricular. Bybee (2014b) noted while coordination between the Common Core State Standards and the NGSS may sometimes be seen negatively, it presents an opportunity to integrate non-fiction reading and writing and mathematics into science and engineering practices within the science classroom.

Students must think abstractly when involved in the quantitative discipline of science. Students are able to understand concepts better when using quantitative tools such as algebra and statistics throughout the science curriculum. Common Core math standards are integrated into the NGSS by identifying what a student must know in order to carry out tasks within each scientific discipline (National Science Teachers Association, 2014).

Students must also possess the ability to effectively construct and communicate arguments when doing science. Reading and writing are essential to the work of scientists and engineers. The NGSS integrate literacy related tasks such as evaluating evidence, constructing explanations, and discussing and critiquing theories. This aides teachers in enhancing science instruction and transforms the science lessons to more reasoning based discussion (National Science Teachers Association, 2014).

Several of the lesson samples submitted by teachers are ones which provided students with opportunities to use math and language arts skills. Science is not a stand alone discipline and must include experiences which incorporate reading, writing, and mathematics (Bybee, 2014b). Engineering design activities such as Hot Air Balloon Challenge and Creating a Construction Crane required students to collect quantitative data through measurements and the use of formulas. This quantitative data is then interpreted and communicated through writing. Students must use skills in writing to describe and explain various aspects of the chosen design. Students were also asked to explain the scientific principles which governed how the engineered models worked. One example of a question which elicits written responses from student is the following: “Describe the pattern that developed between output force and input force as the pulley system design was changed. Explain why this phenomenon occurred?" Questions such as this prompted students to use skills in writing to construct and communicate understandings about the engineering design challenge.

Investigative labs such as Calculating Speed Lab and Investigating the Effects of Energy Drinks on *Daphnia* required students to construct conclusions after analyzing and synthesizing data from the labs. Students use mathematical formulas to calculating speed in Calculating Speed Lab. This information is displayed through graphing. Students use simple math to calculate heartbeats per minutes in the Effects of Energy Drinks on *Daphnia.* Both labs prompted students to use the claim evidence reasoning (CER) learning model. As noted in chapter 2, the CER learning model assists students in developing explanations and promotes the understanding of science through writing (Allen & Rogers, 2015). This model requires students to construct conclusions by substantiating claims with specific pieces of evidence. This information is then used to construct explanations (reasons) for what is observed in the investigation.

Geniverse allows students to engage in a narrative involving the creation of baby dragons. The lessons within *Geniverse* help students investigate heredity and genetics in a virtual laboratory simulation by breeding baby dragons. Students are able to create meaningful and realistic genetic data which can be used to generate conclusions about problems being investigated. The lessons allow students to experiment with mathematical probability and use mathematical thinking to discover patterns appearing in data. *Geniverse* supports writing in science as it is organized based on the 5e (engage, explore, explain, elaborate, and evaluate) instructional model. The 5e instructional model supports writing as students describe, explain, and make connections at different stages of instruction within the model (Bybee, 2014a).

Research Question 2: What resources and support systems do teachers report as being beneficial in the implementation of the NGSS?

The implementation of the NGSS represents a new educational innovation in the field of science education. Science teachers and science teacher educators must address the educational shifts which are taking place in order to see improvement in curriculum, teacher development, assessment and accountability, and student achievement (Bybee, 2014b). There are many variables which can affect teachers' level of success with the implementation of the standards. When teachers were asked about beneficial resources and supports during the process of implementation, the following themes emerged: sustained, relevant professional development; collaboration with colleagues; resources which are NGSS-aligned; and flexible learner-centered classrooms.

Professional development was mentioned most often among the participants as a resource which is or could be very beneficial for science teachers during the implementation process. Relevant, sustained professional development implies teacher participants need professional learning experiences which are directly connected to the pedagogical needs of teachers. It further implies there is a need to have ongoing professional learning. Professional development related to the NGSS should be more than a few isolated training events but, rather, continuous training which is deeply contextual and focused. The professional development activities and exercises should be purposeful and directed toward the pedagogical learning goals. This is consistent with the assertion of McGee & Nutakki (2017). The researchers noted professional development, which is extensive in duration in terms of contact hours and time span, is needed to support shifts in teaching practices.

Several teachers mentioned some form of collaboration as being most helpful during the implementation of the NGSS. Teacher collaboration refers to any professional interaction among teachers with the intent and purpose to problem-solve, develop curriculum, or share professional ideas. Collaboration among colleagues allows for the sharing of similar experiences in the teaching and learning of science. Teachers are able to openly learn from each other by acknowledging successes and challenges with the implementation of the standards. Lesson sharing was a collaborative practice many teachers mentioned was, or would be, helpful. McGee and Nutakki (2017) noted indirect benefits of sustained professional development are possible when teachers who receive professional development share what has been learned with others at school.

The NGSS are still relatively new. Teachers have been creatively approaching the implementation of the standards. Materials are now being marketed which have varying degrees of alignment to the NGSS. Some participants mentioned the availability of NGSS-aligned resources has been very assistive during the implementation process. Effective implementation of the NGSS will be dependent upon the availability of high quality instructional materials. These materials should support features if the NGSS such as phenomena driven exploration, three-dimensional learning, as well as formative and summative assessment (Achieve, 2017). The availability of the Internet presents opportunities for teachers to search among a wide range of NGSS materials located online. Teachers must be able to distinguish between high quality, NGSS-aligned materials and those which are not (Achieve, 2017).

Classrooms in which next generation science is taught are expected to exhibit stark contrasts to traditional science classroom teaching and learning environments. Such classrooms should provide less direct teaching and memorization of isolated facts, and more opportunities to engage in open-ended problem-solving experiences. Duschl and Bybee (2014) noted students should be engaged in investigations which allow opportunities to make choices and decisions during the planning and implementation stages. Teachers should allow students to use different methods of quantifying, collecting, and sharing data. Experiences such as these help students understand how scientific knowledge is generated (Duschl & Bybee, 2014). Students should also be able to use the science and engineering practices outlined in the NGSS to study broader science issues of interest and relevance at a deeper contextual level. This will require teachers to have flexible, learner-centered classrooms.

Research Question 3: What do middle school science teachers report as being challenges or barriers to implementing the NGSS?

There are numerous variables which can have an effect on a teacher's ability to implement a new educational innovation. When teachers in this study were asked about the challenges and barriers experienced during the NGSS implementation process, the following themes were identified: confusion regarding the organization of the standards, varying interpretations of the standards, time needed to implement properly, and meeting personal expectations as a science teacher.

Some participants in this study were adamant about addressing confusion surrounding the NGSS and NGSS document. One participant used the term "overwhelming" to refer to the layout and content of the document. Another participant reported confusion was experienced by colleagues in attempting to determine which statements were standards and which were clarifications of those standards. The NGSS standards document is packed with information and statements representing three dimensions: science content, science and engineering practices, and cross-cutting concepts. Professional development should, in part, be focused on assisting teachers with interpreting and understanding the layout of the NGSS document.

Several participants noted how the standards are interpreted can be a barrier to implementation. Different interpretations of the NGSS by different teachers or science departments can lead to varying styles or levels of implementation. This is especially of concern at the middle school level since the standards are labeled as “middle school” and do not differentiate between the science content and practices for grades 6-7, as done for grades K-5 and 9-12.

The responses from one participant indicated teachers’ personal classroom expectations can serve as a barrier to the implementation of the NGSS. The need to have students perform at a certain level to meet the assessment expectations of teachers and administrations can hinder the kind of teaching and learning intended by the standards. Many school districts now have teacher evaluations linked to student performance and growth. This association could influence the how much Next Generation Science actually occurs in the classroom due to the assessment focus.

The theme referred to most often for this question was *time*. The implementation of the NGSS will take a tremendous amount of time. A Next Generation Science classroom is expected to involve students in ongoing investigations which may take more time than the allotted 40–50 minute class period. One participant expressed frustration with having to start and stop in the middle of an investigation which requires numerous days to complete. Time is also seen as a barrier from a broader perspective. Shifting to Next Generation Science requires many changes in the curriculum. Teachers need time to appropriately and adequately modify, replace, or pilot new curricula. One participant noted there is a desire to make changes to address the new standards; however, it is difficult to do so when overwhelmed by existing teaching responsibilities and lack of time.

Limitations

Qualitative grounded theory research attempts to generate theory from qualitative data. This research method is both iterative and comparative. The researcher constantly makes comparisons among various categories of data to control the level and scope of the developing theory (Sutcliffe, 2016). The focus of this study was to examine teacher perceptions of the Next Generation Science Standards. The researcher's goal was to obtain 20 participants for this study. The actual sample consisted of 15 teacher participants since there were slow and limited responses to the researcher's requests for participation. This study may not be generalizable to all teachers as the study's population was limited to teachers of middle school students. An additional limitation of this study involved the geographic location. Middle-level science teachers who participated in this study were from within or near DuPage County, Illinois. The findings may not be generalizable to other counties as there can be great variation in educational funding, educational philosophies, and teacher experiences.

Recommendations

Teachers who participated in this study had generally positive perceptions of the NGSS. Teacher responses to the survey indicated there is general agreement with the seven conceptual shifts and expectations which come with transitioning to next generation science. The shift to next generation science will not happen easily or in a short period of time. Teachers will need consistent guidance and support while moving toward full alignment of instruction to the NGSS. Those who have reported being in full alignment with the NGSS will also need continued support to remain at this level. Many of the participant responses suggested there is a need for continued professional learning related to the NGSS and time to properly implement the standards. The results of this study also suggest there could be a lack of understanding among teachers regarding the relationship between science and responsible citizenship.

Time

The implementation of a new curricular innovation such as the NGSS requires numerous resources. Time is one of the more critical of these resources (Reiser, 2013). Teachers will need time to make adjustments and changes in curricular practices which have been in place for several years. This may involve consistent collaborative efforts between district curricular leaders and science teachers to evaluate the scope and sequence of the content to be taught, material resources, and assessments. Additional time will also be needed to evaluate the effectiveness of any changes which have been made and implemented and to revise curricular goals and school district expectations. The tremendous workload and the rigorous, fast pace of the school day and the extended school year provide few opportunities for teachers to engage in curricular development for any lengthy period of time appropriate to address these issues. Teachers will need strategically planned time over a period of years as incremental steps are taken to achieve the vision of science education presented in the NGSS.

Professional Development

Professional development must be coherent and should address the specific needs of teachers and school districts (McGee & Nutakki, 2017). Boesdorfer and Greenhalgh (2014) asserted teachers can be heavily connected and engaged with instructional practices which have been used consistently in the classroom for many years. Therefore, science teachers need professional development opportunities which are effective in helping to unlearn and disengage with past teaching practices which are not consistent with the practices inherent in the NGSS.

Changing how middle level students acquire and apply knowledge of scientific concepts implies teachers must also transform methods of engaging students in science. Duschl and Bybee

(2014) recommended teacher preparation programs and professional development in science focus on a core set of pedagogical routines which are attainable, broadly defined as to fit different instructional approaches, and foundational. Such pedagogical routines include: (1) selecting big ideas for inquiry, (2) eliciting students' preconceived ideas, (3) making meaning of scientific phenomena, and (4) eliciting evidence-based explanations. Professional development which guides teachers to consistently apply these routines can improve middle school science teachers' level of comfort when facilitating next generation science classrooms.

The NGSS emphasize the implementation of a complete engineering design experience (Moore, et al., 2015). This means engineering is not to be taught as a standalone discipline, but rather incorporated into the curriculum along with the practices of science. Most teachers in this study felt comfortable incorporating engineering practices into the science curriculum. Many also understand engineering is not limited to the building of large scale, physical projects, but also includes, drawing, modeling, and communicating. It is difficult for some teachers to recognize the many ways engineering can be integrated into the middle school science curriculum. Teachers in general, need assistance in differentiating what engineering is and what it is not. This implies there is a significant need for science teacher professional development focuses on engineering design.

Science and Responsible Citizenship

Several teachers in this study expressed concerns about shift 6: *The standards must prepare students for college, careers, and responsible citizenship.* The NGSS document states students must use science when engaging in practices such as interpreting current events, using technology, or making decisions which affect one's health (Next Generation Science Standards Lead States, 2013). A science curriculum which provides opportunities for students to engage in open-ended and problem based investigations helps to enrich students' understanding of the research practice. Participating in such experiences also empower students to engage as autonomous learners and think critically about actions and decisions (Ruiz-Mallén, Riboli-Sasco, Ribrault, Heras, Laguna, & Perié, 2016). The degree to which students demonstrate skills such as problem solving, critical thinking, responsibility, and teamwork all contribute to one's level of responsible citizenship.

Teachers must make the connections between the science curriculum and responsible citizenship in order for students to see the importance of science in society. When students participate in science which has personal, cultural, or social significance, more meaningful and relevant connections can be made to the world outside of the classroom (Trauth-Nare, 2016). Teachers should be mindful of this when constructing scientific investigations. Investigations should be purposefully constructed so students have opportunities to use and apply skills to address problems of significance in ways similar to how any individual would outside of the classroom.

Model of NGSS Implementation

Shakman and Rodriguez (2015) described an implementation model as a visual representation of a policy, program, or plan of action. Visual models are effective tools which can serve as guides to effective implementation. When information is represented graphically, it may allow for deeper insights which can be garnered quickly and efficiently. The findings from this study have informed the development of the Harris Model of NGSS Implementation (Figure 3). Middle-level science teachers can benefit from using this model as a basic guide when planning

Harris Model of NGSS Implementation

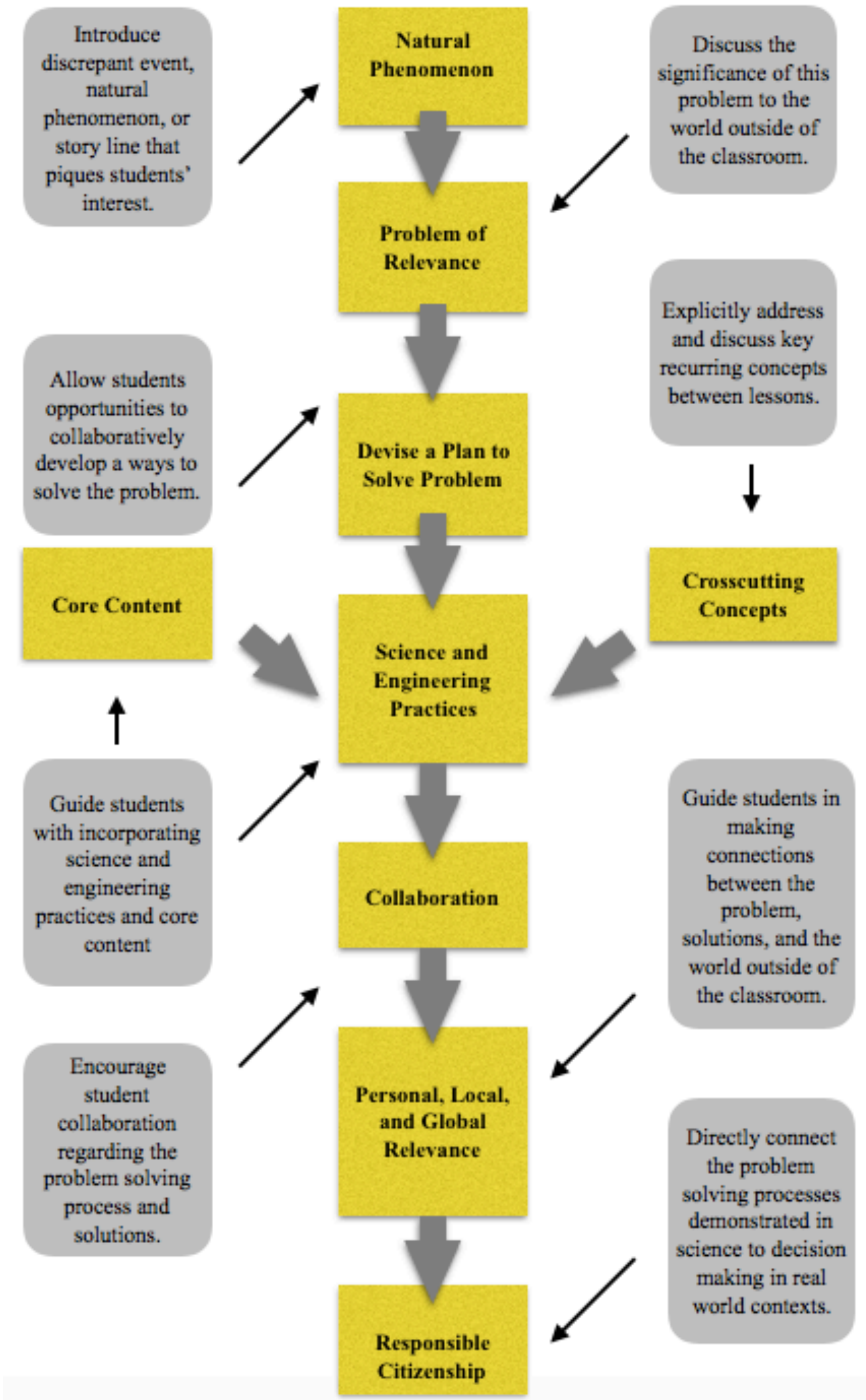

Figure 3: Harris Model of NGSS Implementation

and facilitating next generation science based lessons.

The Harris Model of NGSS Implementation encourages middle level science teachers to follow a logical sequence when facilitating individual science lessons or a science unit. The model prompts teachers to initiate science investigations by introducing story lines, natural phenomena, or discrepant events. These methods help to generate excitement and interest among students. Students should be guided toward investigating problems of relevance. Investigating problems of significance or relevance encourages students' engagement in science (Tas, 2016).

This model also prompts teachers to emphasize responsible citizenship as demonstrated through scientific investigation and problem solving. The findings from this study indicated several teachers did not see the connection between next generation science and responsible citizenship. Responsible citizenship refers to an individual's ability to act responsibly and make choices which positively impact the well-being of oneself and others. Students are simulating the processes of responsible citizenship when presented with opportunities to make choices during the problem solving process (Duschl & Bybee, 2014).

Future Research

Research involving the NGSS is still relatively new. There is valuable information yet to be learned about science teacher perceptions and practices involving the standards. This qualitative grounded theory study was limited to middle-level science teachers in one suburban county in Illinois which is comprised of numerous affluent school districts. Future research should broaden the scope of the study to include more diverse socioeconomic and geographic settings.

The researcher utilized teacher lesson samples to gain information about each teacher's NGSS implementation practices for this study. The next research endeavor should involve direct classroom observations of each participant's teaching practices. Collecting data through classroom observations will allow the researcher greater access and insight into each participants teaching practice.

School leadership can have a great impact on what takes place in the school building. The support of school administration is essential for the success of any curricular innovation (Passmore, 2015). Exploring administrator perceptions of teaching and learning in science can provide valuable information relative to administrators' expectations of teachers in this era of Next Generation Science.

Implications for Leadership

School Administrative Leaders

Teachers in this study have expressed the need for relevant, sustained professional development to assist in the process of NGSS implementation. School administrative leaders should create opportunities for access to appropriate professional development. This includes providing the necessary time for teachers to collaborate, plan, and revise current science curricula.

Teacher Leaders

It is incumbent upon science teachers to take up leadership roles as the U.S. embraces the changing landscape of science education. The NGSS is an educational innovation which will require time and patience to fully implement. Taking on leadership roles involves taking ownership of one's professional learning by seeking appropriate professional development. Nadelson and Seifert (2016) expressed highly effective professional development helps teachers engage in practices of reflection, increases skills of leadership, and provides encouragement for teachers to enact and support change within schools. Teachers who are more engaged and associated with some form of leadership are more likely to embrace innovative change and encourage innovation among colleagues.

Pre-Service Science Teacher Leaders

Pre-service science teachers are at a stage in which there is little or no influence from past teaching practices since many students in such programs have no formal teaching experience. This means pre-service educators have fewer teaching practices to unlearn. Leaders within pre-service science teacher education programs must stay engaged with current research related NGSS. Leaders should be aware of the successes, challenges, and concerns of teachers who are currently facilitating NGSS classrooms. This knowledge allows pre-service science leaders to create learning situations in which new teachers can gain valuable skills relative to the implementation of the NGSS which will be helpful in future science classrooms.

References

American Association for the Advancement of Science. (2013). *AAAS - Project 2061 - Benchmarks for science literacy*. Retrieved from http:// www.project2061.org/ publications/bsl/

American Association for the Advancement of Science. (2017). *Science for all Americans - AAAS - The world's largest general scientific society*. Retrieved from https://www.aaas.org/report/science-all-americans

Achieve. (2015). *The role of learning progressions in competency-based pathways*. Retrieved from https://www.achieve.org/files/Achieve-LearningProgressionsinCBP.pdf

Achieve. (2017). *NGSS district implementation workbook*. Retrieved from https://www.nextgenscience.org/sites/default/files/FINAL%20District%20Implementation%20Workbook_0.pdf

Achieve. (2018). *College and career readiness*. Retrieved from https://www.achieve.org/college-and-career-readiness

Ali, A., & Yusof, H. (2011). Quality in qualitative studies: The case of validity, reliability and generalizability. *Issues in Social & Environmental Accounting, 5*(1/2), 25-64. Retrieved from http://www.iiste.org/Journals/index.php/ISEA/article/view/952/873

Allen, J. & Rogers, M. (2015). Putting ideas on paper: Formulating scientific explanations using the claim, evidence, and reasoning (CER) framework. *Science and Children, 53*(3), 32-37. Retrieved from http://www.nsta.org

American College of Education. (2015). *Institutional Review Board handbook*. Retrieved from https://ace.instructure.com/courses/1418462/files/67704741?module_item_id=15111366

Andrews, L., Higgins, A., Andrews, M., & Lalor, J. (2012). Classic grounded theory to analyze secondary data: Reality and reflections. *Grounded Theory Review*, *11*(1), 12-26. Retrieved from http://groundedtheoryreview.com/2012/06/01/classic-grounded-theory-to- analyse-secondary-data-reality-and-reflections/

Arghode, V. (2012). Qualitative and quantitative research: Paradigmatic differences. *Global Education Journal, 2012*(4), 155-163. Retrieved from http://www.franklin publishing.net/globaleducation.html

Aschbacher, P., Ing, M., & Tsai, S. (2014). Is science me? Exploring middle school students' STE-M career aspirations. *Journal of Science Education & Technology*, *23*(6), 735-743. doi:10.1007/s10956-014-9504-x

Ault, C. R. (2015). *Challenging science standards: A skeptical critique of the quest for unity*. Lanham, MD: Rowman & Littlefield Publishers.

Baatard, G. (2012). A technical guide to designing and implementing effective web surveys. *The Electronic Journal of Business Research Methods*, *10*(2), 101-109. Retrieved from http://www.ejbrm.com/issue/download.html?idArticle=282

Bartholomew, S. (2015). Who teaches the "STE" in STEM? *Technology & Engineering Teacher*, *75*(2), 14-19. Retrieved from https://www.iteea.org/39191.aspx

Baškarada, S. (2014). Qualitative case study guidelines. *The Qualitative Report*, *19*(40), 1-18. Retrieved from http://nsuworks.nova.edu/tqr/vol19/iss40/3

Baturina, D. (2015). In expectation of the theory: Grounded theory method. *Methodological Horizons*, *10*(1), 77-90. Retrieved https://hrcak.srce.hr/file/218606

Best, J., Dunlap, A., & McRel, I. (2014). Next generation science standards: considerations for curricula, assessments, preparation, and implementation. *Mcrel International.* Retrieved from https://www.mcrel.org/standards-curriculum/

Birks, M. & Mills, J. (2015). *Grounded theory: A practical guide.* Los Angeles, CA: Sage Publications, Inc. Retrieved from https://books.google.com/books?id=YsGICwA AQBAJ& printsec=frontcover&source= gbs_ge_summary_r&cad=0#v= onepage&q&f=false

Bismack, A., Arias, A., Davis, E., & Palincsar, A. (2014). Connecting curriculum materials and teachers: Elementary science teachers' enactment of a reform-based curricular unit. *Journal of Science Teacher Education*, *25*(4), 489-512. doi:10.1007/s10972-013-9372-x

Boesdorfer, S., & Greenhalgh, S. (2014). Make room for engineering. *Science Teacher*, *81*(9), 51-55. doi.org/10.2505/4/tst14_081_09_51

Braaten, M., & Windschitl, M. (2011). Working toward a stronger conceptualization of scientific explanation for science education. *Science Education*, 95(4), 639-669. Retrieved from https://pdfs.semanticscholar.org/cfe5/967249899404b35889bea724ba9954c147d2.pdf

Burks, B. A., Beziat, T. L., Danley, S., Davis, K., Lowery, H., & Lucas, J. (2015). Adapting to change: Teacher perceptions of implementing the common core state standards. *Education, 136*(2), 253-258. Retrieved from http://www.project innovation.com/education.html

Bybee, R. (2011). Scientific and engineering practices in K-12 classrooms: Understanding a framework for K-12 science education. *Science and Children*, *49*(4), 10. Retrieved from http://www.nmu.edu/seaborg/sites/DrupalSeaborg/files/UserFiles/Files/NGSS/ Scientific_and_Engineering_Practices_in_K-12_Classrooms_by_Rodger_Bybee.pdf

Bybee, R. (2013). The Next Generation Science Standards and the life sciences. *Science and Children*, *50*(6), 7. Retrieved from http://static.nsta.org/pdfs/ngss/201302_NGSS-Bybee.pdf

Bybee, R. (2014a). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children*. pp. 10-13. Retrieved from https://s3.amazon aws.com/nstacontent/sc140810.pdf?AWSAccessKeyId=AKIAIMRSQAV7P6X4QIKQ&Expires=1528729469&Signature=VJNMNQM94slwCIKE0K3iB%2fPzeRs%3d

Bybee, R. (2014b). NGSS and the next generation of science teachers. *Journal of Science Teacher Education*, *25*(2), 211-221. doi:10.1007/s10972-014-9381-4

California Department of Education. (2014). *Next generation sciences standards - science (CA Dept. of Education)*. Retrieved from http://www.cde.ca.gov/pd/ca/sc/ngssintrod.asp

Callahan, B. & Dopico, E. (2016). Science teaching in science education. *Cultural Studies of Science Education*, *11*(2), 411-418. doi:10.1007/s11422-015-9703-7

Campbell, T. & Smith, E. (2013). Envisioning the changes in teaching framed by the National Science Education Standards-Teaching Standards. *International Journal of Education in Mathematics, Science, and Technology, 1*(3), 162-183. Retrieved from http://ijemst.com/home.html

Capraro, R & Han, S. (2014). STEM: The education frontier to meet 21st century challenges. *Middle Grades Research Journal*, 9(3), xv-xvii. Retrieved from http://fac.ksu.edu.sa/sites/default/files/stem_the_education_frontier_to_meet_21st_century_challenges.pdf

Cardoza, Y., & Tunks, J. (2014). The bring your own technology initiative: An examination of teachers' adoption. *Computers in the Schools*, *31*(4), 293-315. doi:10.1080/07380569.2014.967626

Carr, R., Bennett, L., and Strobel, J. (2012). Engineering in the k-12 stem standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education*, *101*(3), 539–564. doi:10.1002/j.2168-9830.2012.tb00061.x

Charmaz, K. (2014). *Constructing grounded theory*. Los Angeles, CA: Sage Publications, Inc.

Chenail, R. J. (2011). Interviewing the investigator: Strategies for addressing instrumentation and researcher bias concerns in qualitative research. *Qualitative Report, 16*(1), 255-262. Retrieved from: http://nsuworks.nova.edu/tqr/vol16/iss1/16/

Cho, Y. & Lee, E. (2014). Reducing confusion about grounded theory and qualitative content analysis: Similarities and differences. *Qualitative Report, 19*(32), 1-20. Retrieved from https://nsuworks.nova.edu/tqr/vol19/iss32/2/

Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school science, teachers, and popular science. *International Journal of Environmental & Science Education*, *6*(2), 141-159. Retrieved from http://www.ijese.net/

Creswell, J. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage Publications, Inc.

Crowell, A. & Schunn, C. (2016). Unpacking the relationship between science education and applied scientific literacy. *Research in Science Education*, *46*(1), 129-140. doi:10.1007/s11165-015-9462-1

DeBoer, G. (2011). The globalization of science education. *Journal of Research in Science Teaching*, *48*(6), 567-591. doi:10.1002/tea.20421

Department of Economic Development and Planning. (2011). *DuPage County statistical profile*. Retrieved from https://www.dupageco.org/EDP/Regional_Planning/Docs/32392/

Desimone, L. (2013). Reform before NCLB. *The Phi Delta Kappan, 94*(8), 59-61. Retrieved from http://journals.sagepub.com/doi/full/10.1177/003172171309400814

Dixon, R. & Brown, R. (2012). Transfer of learning: Connecting concepts during problem solving. *Journal of Technology Education, 24*(1), 2-17. doi: 10.21061/jte.v24i1.a.1

Doody, O. & Noonan, M. (2013). Preparing and conducting interviews to collect data. *Nurse Researcher*, *20*(5), 28-32. doi: 10.7748/nr2013.05.20.5.28.e327

Duschl, R. & Bybee, R. (2014). Planning and carrying out investigations: An entry to learning and to teacher professional development around NGSS science and engineering practices. *International Journal of STEM Education, 1*(1), 1-9. doi:http://dx.doi.org/10.1186/s40594-014-0012-6

Edmonson, D., Edwards, Y. & Boyer, S. (2012). Likert scales: A marketing perspective. *International Journal of Business, Marketing, & Decision Science*, *5*(2), 73-85. Retrieved from http://www.iabpad.com/journals/international-journal-of-business-marketing-and-decision-sciences/

Edwards, S. (2015). Active learning in the middle grades. *Middle School Journal*, *46*(5), 26-32. doi: doi.10.1080/00940771.2015.11461922

Ewing, M. (2015). EQuIP-ped for success. *Science Scope, 38*(5), 13-15. Doi: 10.2505/4/sc15_052_05_9

Feinstein, N. (2011). Salvaging science literacy. *Science Education*, *95*(1), 168-185. doi: 10.1002/sce.20414

Fuller, S. (2013). The secret life of science in the Second World War. *New Scientist*, *220*(2938), 48-49. doi:10.1016/s0262-4079(13)62442-2

Fullan, M., & Scott, G. (2016). Practice change: Savvy leadership to guide your institution into the future. *The Successful Registrar*, *16*(6), 9-9. doi: 10.1002/tsr

Fullan, M. (2014). *Teacher development and educational change*. New York, NY: Routledge Taylor and Francis.

Gentles, S., Charles, C., Ploeg, J., & McKibbon, K. (2015). Sampling in qualitative research: Insights from an overview of the methods literature. *Qualitative Report*, 20(11), 1772. Retrieved from https://nsuworks.nova.edu/tqr/vol20/iss11/5/

Glasersfeld, V. (1990). An exposition of constructivism: Why some like it radical. *Journal for Study in Mathematics Education*, *4*(6), 102-116. Retrieved from http://www.univie.ac.at/constructivism/EvG/papers/127.pdf

Gray, W. S., & Staiger, R. C. (1969). *The teaching of reading and writing: An international survey* (No. 10). UNESCO. Retrieved from *http://unesdoc.unesco.org/images/*0000/000029/002929eo.pdf

Haag, S. & Megowan, C. (2015). Next Generation Science Standards: A national mixed-methods study on teacher readiness. *School Science & Mathematics*, *115*(8), 416-426. doi:10.1111/ssm.12145

Hall, G. E., Dirksen, D. J., & George, A. A. (2013). *Measuring implementation in schools: Levels of use*. Austin, TX: American Institutes for Research

Hall, G. E., Loucks, S. F., Rutherford, W. L., & Newlove, B. W. (1975). Levels of Use of the Innovation: A framework for analyzing innovation adoption. *Journal of Teacher Education*, *26*(1), 52. Retrieved from http://journals.sagepub.com/doi/abs /10.1177/002248717502600114?journalCode=jtea

Heitin, L. (2015, May 5). Districts out ahead of states in adopting science standards. *Education Week*. Retrieved from http://www.edweek.org/ew/articles/2015/05/06/districts-out-ahead-of- states-in-adopting.html#map

Higginbottom, G. & Lauridsen, E. (2014). The roots and development of constructivist grounded theory. *Nurse Researcher, 21*(5), 8-13. doi: 10.7748/nr.21.5.8.e1208

Houseal, A. (2016). A visual representation of three-dimensional learning: A model for understanding the power of the framework and the NGSS. *Electronic Journal of Science Education*, *20*(9), 1-7. Retrieved from http://ejse.southwestern.edu/article/view/16337

Illinois State Board of Education. (2016). *Illinois learning standards - science.* Retrieved from http://www.isbe.state.il.us/nILS/science/default.htm

Ireland, J., Watters, J., Brownlee, J., & Lupton, M. (2012). Elementary teachers' conceptions of inquiry teaching: Messages for teacher development. *Journal of Science Teacher Education*, *23*(2), 159-175. doi:10.1007/s10972-011-9251-2

Jackson, J., Durham, A., Dowell, S., Sockel, J., & Boynton, I. (2016). Claims and evidence: Creating opportunities for students to practice speaking and writing about science. *Science and Children*, *53*(4), 64-69. Retrieved from http://www.nsta.org /elementaryschool/

Jones, B., & Jaffe, A. (2015). *The changing frontier: Rethinking science and innovation policy*. Chicago, IL: University of Chicago Press. Retrieved from http://www.nber.org/chapters/c13027.pdf

Kellmereit, B. (2015). Focus groups. *International Journal of Sales, Retailing & Marketing*, *4*(9), 42-52. Retrieved from http://www.ijsrm.com/ijsrm/home.html

Kennedy, T. & Odell, M. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246-258. Retrieved from http://www.icaseonline.net/sei/september2014/p1.pdf

Kim, K. H., VanTassel-Baska, J., Bracken, B. A., Feng, A., & Stambaugh, T. (2014). Assessing science reasoning and conceptual understanding in the primary grades using standardized and performance-based assessments. *Journal of Advanced Academics, 25*(1), 47-66. doi: 10.1177/1932202x14520946

Klieger, A. & Yakobovitch, A. (2011). Perception of science standards' effectiveness and their implementation by science teachers. *Journal of Science Education & Technology*, *20*(3), 286-299. doi:10.1007/s10956-010-9253-4

Klute, M., Apthorp, H., Harlacher, J., & Reale, M. (2017). *Formative assessment and elementary school student academic achievement: A review of the evidence. REL 2017-259*. Regional Educational Laboratory Central. Washington, DC 20208. Retrieved from https://ies.ed.gov/ncee/edlabs/projects/project.asp?projectID=449

Krajcik, J. K. (2015). Three-dimensional instruction. *Science Teacher*, *82*(8), 50-52. Retrieved from http://static.nsta.org/files/tst1508_50.pdf

Krajcik, J., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards. *Journal of Science Teacher Education*, 25(2), 157-175. doi:10.1007/s10972-014-9383-2

Laverty, J., Underwood, S. Matz, R., Posey, L., Carmel, J., Caballero, M., & Cooper, M. (2016). Characterizing college science assessments: The three-dimensional learning assessment protocol. *Plos ONE*, *11*(9), 1-21. doi:10.1371/journal.pone.0162333

Lawrence, J. & Tar, U. (2013). The use of grounded theory technique as a practical tool for qualitative data collection and analysis. *Electronic Journal of Business Research Methods*, 11(1), 29-40. Retrieved from http://www.ejbrm.com/main.html

Leung, L. (2015). Validity, reliability, and generalizability in qualitative research. *Journal of Family Medicine and Primary Care*, 4(3), 324-327. Retrieved from http://doi.org/10.4103/2249-4863.161306

Linn, M., Gerard, L., Matuk, C., & McElhaney, K. (2016). Science education: From separation to integration. *Review of Research in Education, 40*(1), pp. 529 - 587 doi: 10.3102/0091732X16680788

Loucks, S. F., & Hall, G. E. (1979). Implementing innovations in schools: A concerns-based approach. American EducationResearch Association, San Francisco, April 12, 1979 Retrieved from http://www.aera.net/

Lowe, C., & Zemliansky, P. (2011). Introduction to primary research: Observations, surveys, and interviews. In *Writing spaces: Readings on writing*. Retrieved from http://www.wordslingingwoman.com/1-201-SP14/ENGL201_driscoll--introduction-to-primary-research.pdf

Mayer, I. (2015). Qualitative research with a focus on qualitative data analysis. *International Journal of Sales, Retailing & Marketing*, *4*(9), 53-67. Retrieved from http://www.ijsrm.com/ijsrm/home.html

McFarlane, D. (2013). Understanding the challenges of science education in the 21st century: New opportunities for scientific literacy. *International Letters of Social and Humanistic Sciences*, *4*(1), 35-44. Retrieved from https://www.scipress.com/ILSHS.4.35

McGee, S., & Nutakki, N. (2017). The impact of adapting a general professional development framework to the constraints of in-service professional development on the next generation science standards in urban settings. *Journal of Urban Learning, Teaching, and Research, 13*(1), 73-89. Retrieved from https://aera-ultr.wixsite.com/ultr

Mehta, J. (2015). Escaping the shadow: "A Nation at Risk" and its far-reaching influence. *American Educator*, *39*(2), 20-26. Retrieved from http://www.aft.org/sites/default/files/ae_summer2015mehta.pdf

Merriam, S. & Tisdell, E. (2015). *Qualitative research: A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). NGSS and the landscape of engineering in K-12 state science standards. *Journal of Research in Science Teaching*, *52*(3), 296-318. doi:10.1002/tea.21199

Moreau, L. K. (2014). Who's really struggling?: Middle school teachers' perceptions of struggling readers. *RMLE Online: Research in Middle Level Education*, *37*(10). doi:10.1080/19404476.2014.11462113

Morrison, C. (2014). "From ‘sage on the stage’ to ‘guide on the side’: A good start". *International Journal for the Scholarship of Teaching and Learning*, *8*(1), 1-17. doi.org/10.20429/ijsotl.2014.080104

Moye, J., Jones, V., & Dugger, W. (2015). Status of technology and engineering education in the United States: A fifth report of the findings from the states (2014-15). *Technology & Engineering Teacher*, *74*(7), 30-36. Retrieved from https://www.iteea.org/Activities/2142/Status_for_Technology_Education/Status_Articles/77875.aspx

Murnane, R., & Levy, F. (2001). Will standards-based reforms improve the education of students of color? Retrieved from http://www.ntanet.org/NTJ/54/2/ntj-v54n02p401-16- will-standards-based-reforms.pdf

Nadelson, L. & Seifert, A. (2016). Putting the pieces together: A model of K-12 teachers' educational innovation implementation behaviors. *Journal of Research in Innovative Teaching*, *9*(1), 47-67. Retrieved from https://www.nu.edu/assets/resources/pageResources/journal-of-research-in-innovative-teaching-volume-9.pdf

National Association of State Boards of Education. (2017). *NASBE - Next generation science standards*. Retrieved from http://www.nasbe.org/project/next-generation-science-standards/

National Center for Science Education. (2014). *Wyoming blocks NGSS over climate*. Retrieved from http://ncse.com/news/2014/03/wyoming-blocks-ngss-over-climate-0015455

National Education Goals Panel. (1991). *The National Education Goals report*. Retrieved from http://govinfo.library.unt.edu/negp/reports/99rpt.pdf

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press. Retrieved from https://www.nap.edu/read/4962/chapter/1

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press. Retrieved from http://www.nextgenscience.org/framework-k%E2%80%9312-science-education

National Research Council. (2015). *Guide to implementing the Next Generation Science Standards*. Committee on Guidance on Implementing the Next Generation Science Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education, Washington, DC: The National Academies Press. dos:10.17226/18802

National Science Teacher Association. (2014). *Making connections to CommonCcore*. Retrieved from http://ngss.nsta.org/making-connections-common-core.aspx

Next Generation Science Standards. (2014). *EQuIP rubric for science released*. Retrieved from http://www.nextgenscience.org/news/equip-rubric-science-released

Next Generation Science Standards Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press. doi:10.17226/18290

Oliveira, A. A., Wilcox, K., Angelis, J., Applebee, A., Amodeo, V., & Snyder, M. (2013). Best practice in middle-school science. *Journal of Science Teacher Education*, 24(2), 297-322. doi:10.1007/s10972-012-9293-0

Park, J. & Park, M. (2016). Qualitative versus quantitative research methods: Discovery or justification? *Journal of Marketing Thought*, 3(1), 1-7. doi:10.15577/jmt.2016.03.01.1

Passmore, C. (2015). Shifting to NGSS-aligned classrooms. *Leadership*, *24*(4). 24-27. Retrieved from http://journals.sagepub.com/home/lea#

Patton, M. Q. (2014). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc. Retrieved from https://bibliotecadecienciassociales.files.wordpress.com/2014/02/qualitative-research-evaluation-methods-by-michael-patton.pdf

Pense, S., Freeburg, B., & Clemons, A. (2015). Implementation of Common Core State Standards: Voices, positions, and frames. *Career & Technical Education Research*, 40(3), 157-173. doi:10.5328/cter40.3.157

Peterson, P., Woessmann, L., Hanushek, E., & Lastra Anadon, C. (2011). Are U.S. students ready to compete? *Education Next*, *11*(4), 50-59. Retrieved from http://educationnext.org/are-u- s-students-ready-to-compete/

Pratt, H. (2013). Conceptual shifts in the Next Generation Science Standards: Opportunities and challenges. *Science Scope. 37*(1), 6-11. Retrieved from http://www.jstor.org/ stable/43184286

Pruitt, S. (2014). The next generation science standards: The features and challenges. *Journal of Science Teacher Education*, *25*(2), 145-156. doi:10.1007/s10972-014-9385-0

Public School Review. (2016). *DuPage County, IL public middle schools*. Retrieved from http://www.publicschoolreview.com/illinois/dupage-county/middle

Reiser, B. (2013). What professional development strategies are needed for successful implementation of the Next Generation Science Standards. *Paper presented at the Invitational Research Symposium on Science Assessment. K-12 Center at ETS.* Retrieved from http://www.csai-online.org/resources/what-professional-development-strategies-are-needed-successful-implementation-next

Robinson, O. C. (2014). Sampling in interview-based qualitative research: A theoretical and practical guide. *Qualitative Research in Psychology*, *11*(1), 25-41. doi: 10.1080/14780887.2013.801543

Rothman, R. (2012a). A common core of readiness. *Educational Leadership*, *69*(7), 10-15. Retrieved from http://www.ascd.org/publications/educational-leadership /apr12/vol69/num07/A-Common-Core-of-Readiness.aspx

Rothman, R. (2012b). How we got here: The emergence of the Common Core State Standards. *State Education Standard*, *12*(2), 4-8. Retrieved from http://www.nasbe.org/wp-content/ uploads/How-We-Got-Here-The-Emergence-opf-the-Common-Core-State-Standards.pdf

Ruiz-Mallén, I., Riboli-Sasco, L., Ribrault, C., Heras, M., Laguna, D., & Perié, L. (2016). Citizen science: Toward transformative learning. *Science Communication*, *38*(4), 523-534. doi:10.1177/1075547016642241

Sarieddine, D., & BouJaoude, S. (2014). Influence of teachers' conceptions of the nature of science on classroom practice. *EURASIA Journal of Mathematics, Science & Technology Education*, *10*(2), 135-151. Retrieved from http://www.iserjournals.com/ journals/eurasia/articles/10.12973/eurasia.2014.1024a

Savasci, F. & Berlin, D. (2012). Science teacher beliefs and classroom practice related to constructivism in different school settings. *Journal of Science Teacher Education*, 23(1), 65-86. doi:10.1007/s10972-011-9262-z

Schatz, D. & Fraknoi, A. (2017). Total eclipse. *Science Teacher*, *84*(3), 33-38. Retrieved from https://www.questia.com/library/p2442/the-science-teacher

Schramm-Possinger, M. (2016). Pre-service teachers' humanistic vs. custodial beliefs: Before and after the student teaching experience. *Journal of Education and Training Studies*, *4*(1), 74-87. doi: 10.11114/jets.v4i1.1080

Sen, O. & Sarı, U. (2017). Pre-service science teachers' beliefs about science teaching and perception of the nature of science. *Electronic Journal of Science Education*, *21*(1), 1-14. Retrieved from http://ejse.southwestern.edu/article/view/16409

Senan, D. (2013). Infusing BSCS 5E Instructional model with multimedia: A promising approach to develop 21st century skills. *Journal on School Educational Technology*, *9*(2), 1-7. doi: https://doi.org/10.26634/jsch.9.2.2494

Shakman, K., & Rodriguez, S. (2015). *Logic models for program design, implementation and evaluation*. Retrieved from https://ies.ed.gov/ncee/edlabs/regions/northeast/pdf/ REL_2015057.pdf

Shernoff, D. J., Sinha, S., Bressler, D. M., & Schultz, D. (2017). Teacher perceptions of their curricular and pedagogical shifts: Outcomes of a project-based model of teacher professional development in the Next Generation Science Standards. *Frontiers in Psychology*, *8*(1), 1-16. doi:10.3389/fpsyg.2017.00989

Shiang-Kwei Wang, S., Hui-Yin Hsu, H., & Posada, J. (2014). Evolutionary technology. *Science Scope*, *37*(6), 37-42. Retrieved from http://digital.nsta.org/publication/?i=193005 &article_id=1614472&view=articleBrowser&ver=html5#{%22issue_id%22:193005,% 22view%22:%22articleBrowser%22,%22article_id%22:%221614472%22}

Simon, M. K., & Goes, J. (2013). Scope, limitations, and delimitations. *Dissertation and Scholarly Research: Recipes for Success*. Retrieved from http://dissertation recipes.com/wp-content/uploads/2011/04/ limitationscopedelimitation1.pdf

Smith, J., & Nadelson, L. (2017). Finding alignment: The perceptions and integration of the Next Generation Science Standards practices by elementary teachers. *School Science & Mathematics*, *117*(5), 194-203. doi:10.1111/ssm.12222

Spiegel, L., Quan, A., & Shimajyo, Y. (2014). *NGSS implementation pathway*. Retrieved from https://ngss.sdcoe.net/NGSS-Implementation-Pathway

Stubbs, E. E., & Myers, B. B. (2016). Part of what we do: Teacher perceptions of STEM integration. *Journal of Agricultural Education*, *57*(3), 87-100. doi:10.5032/jae.2016.03087

Sutcliffe, A. (2016). Grounded theory: A method for practitioner research by educational psychologists. *Educational & Child Psychology*, *33*(3), 44-54. Retrieved from https://www1.bps.org.uk/publications/member-network-publications/member-publications/educational-child-psychology

Sutton, J., & Austin, Z. (2015). Qualitative research: Data collection, analysis, and management. *The Canadian Journal of Hospital Pharmacy*, *68*(3), 226–231. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4485510/

Tas, Y. (2016). The contribution of perceived classroom learning environment and motivation to student engagement in science. *European Journal of Psychology of Education, 31*(4), 557-577. doi:http://dx.doi.org/10.1007/s10212-016-0303-z

Thornton, E., West, C. E., & Alquist, A. (1999). Extent of teacher use of a mathematics curriculum innovation in one district: Years 1 and 2 levels of use (LoU). *Journal of Classroom Interaction*, *34*(1), 9-17. Retrieved from https://www.jstor.org /stable/23870389?seq=1#page_scan_tab_contents

Trauth-Nare, A. (2016). Re-envisioning scientific literacy as relational, participatory thinking and doing. *Cultural Studies of Science Education*, *11*(2), 327-334. doi:10.1007/ s11422-015-9676-6

Trygstad, P., Smith, P., Banilower, E., Nelson, M., & Horizon Research. (2013). *The status of elementary science education: Are we ready for the Next generation science standards?* Retrieved from http://www.horizon-research.com/2012nssme/wp-content/uploads/2013/01/Ready-for-the-NGSS-public.pdf

Uri, T. (2015). The strengths and limitations of using situational analysis grounded theory as research methodology. *Journal of Ethnographic & Qualitative Research*, *10*(2), 135-151. Retrieved from http://www.jeqr.org/

U.S. Department of Education. (1983). *A nation at risk*. [Website]. Retrieved from https://www2.ed.gov/ pubs/NatAtRisk/index.html

U.S. Department of Education. (2010). *College and career ready standards assessment*. [Website]. Retrieved from https://www2.ed.gov/policy/elsec/leg/blueprint/faq/college-career.pdf

U.S. Department of Education. (2016). *Science, technology, engineering and math: Education for global leadership.* [Website]. Retrieved from http:// www.ed.gov/stem

Waldrop, M. (2015). Why we are teaching science wrong, and how to make it right. *Nature*, *523*(7560), 272-274. doi:10.1038/523272a

White House Office of the Press. (2015). *Remarks by the president at white house Science fair.* Retrieved from https://obamawhitehouse.archives.gov/the-press-office/2015/03/23/ remarks-president-white-house-science-fair

Willard, T. (2013). A look at the Next Generation Science Standards. *Science Scope, 80*(3), 36. Retrieved from http://nstahosted.org/pdfs/ngss/InsideTheNGSSBox.pdf

Wilson, C. (2013). Questionnaires and surveys. *Credible Checklists and Quality Questionnaires*, *5*(1), 29-79. doi:10.1016/b978-0-12-410392-4.00002-7

Wissehr, C., Concannon, J., & Barrow, L. H. (2011). Looking back at the Sputnik era and its impact on science education. *School Science & Mathematics*, 111(7), 368-375. doi: 10.1111/j.1949-8594.2011.00099.x

Wyss, V., Heulskamp, D., & Siebert, C. (2012). Increasing middle school student interest in STEM careers with videos of scientists. *International Journal of Environmental and Science Education*, *7*(4), 501-522. Retrieved from http://www.ijese.net/

Yilmaz, K. (2013). Comparison of quantitative and qualitative research traditions: Epistemological, theoretical, and methodological differences. *European Journal of Education*, *48*(2), 311-325. doi:10.1111/ejed.12014

Yore, L. D., & Tippett, C. D. (2014). Reading and science learning. *Encyclopedia of Science Education*, 1-9. doi:10.1007/978-94-007-6165-0_130-2

Appendix A:

INFORMED CONSENT FORM

Prospective Research Participant: Read this consent form carefully and ask as many questions as you like before you decide whether or not to participate in this research study. You are free to ask questions at any time before, during, or after your participation in this research.

Project Information	
Project Title: Examining Middle School Teachers' Perceptions of the Next Generation Science Standards	
Principal Investigator: Milton G. Harris, M.A.T, M.Ed.	**Organization:** American College of Education
Email: milton_glenn@yahoo.com	**Telephone:** 1-708-415-2125
Principal Investigator's Mentor/Chair: Dr. Imani Akin	**Organization and Position:** American College of Education Professor of Leadership - Curriculum and Instruction
Email: imani.Akin@ace.edu	**Telephone:**

Introduction

My name is Milton Harris and I am a graduate student at the American College of Education. I am conducting research in the field of education (curriculum and instruction) under the guidance of Dr. Imani Akin, Ed.D. I am inviting you to participate in a research study involving teacher perceptions of the Next Generation Science Standards (NGSS). I am now going to explain the study to you. Please feel free to ask any questions that you may have about the research. I will be happy to explain anything in greater detail.

Purpose of the Research

The purpose of this dissertation study is to examine how teachers of middle school science conceptualize the NGSS. Knowledge gained from this study can be used to better inform educational leaders when preparing middle school science teachers to facilitate classrooms with NGSS-based curricula.

Description of Methodology

The extent of your participation in this research study will include the following:

- the completion of one survey (10 minutes).
- the completion of 1 interview (30 minutes).

- the voluntary sharing of a Next Generation Science based lesson plan or lesson sample that has been used in your classroom.

Participant Selection

You have been invited to participate in this research because of your experiences as a middle school science teacher. Your experience and insight can contribute much to the understanding of science education and the implementation of the NGSS.

Voluntary Participation

Your involvement in the study is voluntary, therefore you may choose to participate or not. The choice you make has no bearing on your employment or any employment-related evaluations or reports. You may change your mind and stop participating even if you agreed to do so earlier.

Procedures

If you agree to participate in this study, you will be asked to complete an initial survey. The survey will contain closed-ended and open-ended questions which will aid me in identifying your teaching experience and current grade, and general information about your level of familiarity, understanding, and comfort with the NGSS.

Based on your survey responses, you may also be asked to participate in a 30-minute semi-structured interview. The interview may take place in person, over the phone, over Skype (or similar communication platform). During the interview, questions will be asked which will assist me in gaining more in-depth information about your perceptions, level of comfort with teaching practices relevant to NGSS, your ideas about factors that serve as challenges to NGSS implementation, and resources that will support the implementation of NGSS. Any curricular documents you agree to share may be transferred personally as hardcopies or electronically via email.

Duration

The collection of information will take place over the course of 1 month, during which time you will be asked to complete the initial survey, the semi-structured interview, and deliver relevant curricular document(s) you feel comfortable sharing.

Risks

If you choose to participate in this study, you will be asked to share information that is relevant to your teaching practice. You may feel uncomfortable sharing this information. You do not have to answer any question if you do not wish to do so. You do not have to give reasons for not responding to any question.

Benefits

Your participation in this study on middle school science teachers' perceptions about the NGSS will provide valuable information regarding teacher beliefs, interpretations, and needs relevant to the implementation of the NGSS. Knowledge gained from this study may be used to inform educational leaders when preparing middle school science teachers to facilitate classrooms with NGSS-based curricula.

Confidentiality

Information about you or information you provide will not be shared to anyone. Survey information, interview data, and documentary sources you share will be kept in a secured (locked) file to which only I have access. A special pseudonym will be assigned to your information sources. Your name will not be listed directly on any information you provide.

Sharing of Results

The research findings of this study will be organized and written into a formal dissertation. The dissertation will be shared more broadly with my dissertation committee. The results may also be published so that stakeholders who have a vested interest in the field of science education may learn from this research. You will receive a summary of the results. Your contributions will be anonymous.

Right to Refuse or Withdraw

As mentioned earlier, your participation in this study is voluntary. You have the right to withdraw from the study at any time.

Certificate of Consent

I have read the information about this study. I have had the opportunity to ask questions about the study and these questions have been answered to my satisfaction. I consent voluntarily to be a participant in this study.

Print or Type Name of Participant: ____

Signature of Participant: ______________________________ Date: ____________

I confirm that the participant was given an opportunity to ask questions about the study and all of the questions asked by the participant have been answered to the best of my ability. I confirm that the individual has not been coerced into giving consent and the consent has been given freely and voluntarily. A copy of this consent form has been provided to the participant.

Print or Type Name of Principal Investigator:______________________________________

Signature of Principal Investigator: ________________________ Date: ____________

Appendix B:

Letter to School District Superintendents

Dear District Superintendent,

My name is Milton Harris and I am a graduate student at American College of Education. I am conducting research in the field of education (curriculum and instruction) under the guidance of Dr. Imani Akin, Ed.D. The title of my study is *Examining Middle School Teachers' Perceptions of the Next Generation Science Standards (NGSS)*.

The purpose of my study is to examine how teachers of middle school science conceptualize the NGSS. The results of this study will provide valuable information regarding teacher beliefs, interpretations, and needs relevant to the implementation of the NGSS. Knowledge gained from this study may be used to inform educational leaders when preparing middle school science teachers to facilitate classrooms with NGSS-based curricula.

I am writing to request your permission to invite middle school science teachers in your district to participate in this study. The study is limited to science teachers who teach sixth, seventh, or eighth grade students since these grade levels fall into the middle school range.

The extent of each teacher's participation in the study will include the following: the completion of one initial survey (10 minutes), the completion of 1 interview (if selected - 30 minutes), the voluntary sharing of a Next Generation Science based lesson sample that has been used in the classroom (if selected for an interview).

All information and data gathered from this study will be kept confidential and will not be shared with anyone. The names of schools and individual teachers will not be disclosed or written on documents that contain information and data that has been collected. Participation in this study is voluntary and teachers have the right to withdraw from the study at any time.

Any teacher who agrees to participate will be contacted by email. I will introduce myself and the purpose of the study. The teacher will be provided with a copy of an Informed Consent Release Form which explains the details of the study. The teacher will be given the opportunity to ask questions about the study. Once all questions have been addressed and the Informed Consent Release form has been signed and returned, the data collection process will begin.

Please let me know whether or not I have your permission to invite science teachers within your building to participate in this study. If you have questions or would like more information about the study, please contact me using the contact information listed below. Please complete and submit the following form indicating your decision. Thank you for taking the time to consider this opportunity.

Sincerely,

Milton G. Harris

Project Information	
Project Title: Examining Middle School Teachers' Perceptions of the Next Generation Science Standards	
Principal Investigator: Milton G. Harris	**Organization:** American College of Education
Email: milton_glenn@yahoo.com	**Telephone:** 1-708-415-2125
Principal Investigator's Mentor/Chair: Dr. Imani Akin	**Organization and Position:** American College of Education Professor of Leadership - Curriculum and Instruction
Email: imani.Akin@ace.edu	**Telephone:** (844)-526-8588

_______ I **give** the principal investigator permission to contact and invite middle school science teachers in my school building to participate in this research study.

_______ I **do not give** the principal investigator permission to contact and invite middle school science teachers in my school building to participate in this research study.

Name of School District: ____

Name of School District Leader (Print): ____

Signature of School District Leader: ____

Date: ____

Appendix C:

Letter Requesting Science Teacher Participation

Dear Middle School Science Educator,

My name is Milton Harris and I am a graduate student at American College of Education. I am conducting research in the field of education (curriculum and instruction) under the guidance of Dr. Imani Akin, Ed.D. The title of my study is *Examining Middle School Teachers' Perceptions of the Next Generation Science Standards (NGSS)*.

The purpose of my study is to examine how teachers of middle school science conceptualize the NGSS. The results of this study will provide valuable information regarding teacher beliefs, interpretations, and needs relevant to the implementation of the NGSS. Knowledge gained from this study may be used to inform educational leaders when preparing middle school science teachers to facilitate classrooms with NGSS-based curricula.

Earlier, I communicated with your building principal and received permission to reach out to teachers of 6th, 7th, and 8th grades in your building. I am writing you to request your participation in this study. The extent of your participation in the study will include the following: the completion of one initial survey (10 minutes), the completion of 1 interview (if selected - 30 minutes), the voluntary sharing of a Next Generation Science based lesson plan or lesson sample that has been used in the classroom (if selected for an interview).

All information and data gathered from this study will be kept confidential and will not be shared with anyone. Your name or the name of your school will not be disclosed or written on documents which contain information and data that has been collected. Participation in this study is completely voluntary and you have the right to withdraw from the study at any time.

If you agree to participate in this study, you will be provided with a copy of an Informed Consent Release form which explains the details of the study. You will be given the opportunity to ask questions about the study. Once all questions have been addressed and the Informed Consent Release form has been signed and returned, I will begin collecting data.

Please let me know whether or not you would be interested participating in this study. If you are interested, an Informed Consent Release form will be sent to you for completion. If you have questions or would like more information about the study, please contact me using the contact information listed below. Please complete and submit the following form indicating your decision. Thank you so much for taking the time to consider this opportunity.

Sincerely,

Milton G. Harris

Project Information	
Project Title: Examining Middle School Teachers' Perceptions of the Next Generation Science Standards	
Principal Investigator: Milton G. Harris	**Organization:** American College of Education
Email: milton_glenn@yahoo.com	**Telephone:** 1-708-415-2125
Principal Investigator's Mentor/Chair: Dr. Imani Akin	**Organization and Position:** American College of Education Professor of Leadership - Curriculum and Instruction
Email: imani.Akin@ace.edu	**Telephone:**

________ **I am interested** in this research study on Middle School Teachers' Perceptions of the Next Generation Science Standards and **would like to participate**.

________ **I am interested** in this research study on Middle School Teachers' Perceptions of the Next Generation Science Standards and **would like more information before deciding to participate**.

________ I am not interested in this research study on Middle School Teachers' Perceptions of the Next Generation Science Standards.

Print Name of School: ____

Print Name of Middle School Teacher: ____

Phone Number: ____

Email: ____

Mailing Address: ____

Signature of Middle School Teacher: ____

Date: _________________________________

Appendix D: Middle Level Science Teacher Perception Survey

Middle Level Science Teacher Perceptions of NGSS Survey

Using the NGSS Pathway Model, identify where you feel you are as an educator on the pathway toward NGSS implementation.

Awareness		Transition	Implementation
Initial Exposure to NGSS	**Deepening Understanding of NGSS**	**Planning Instruction around NGSS**	**Full Alignment of Instruction to NGSS**
- first exposure to NGSS and critical components - engaged in initial research on the NGSS - first exposure to professional development focused on the NGSS	- beyond initial exposure to the NGSS - continued professional development on the NGSS - greater understanding of the purpose of the NGSS and its critical components	- experimentation by taking one or more existing lessons and translating them into an NGSS based lessons - experimentation with the NGSS by planning lessons and/or units around specific standards - guiding questions may be used to direct classwork	- guiding questions that come from students may be used to direct classwork - all instruction is designed and planned around the NGSS - formative and summative assessments are designed based on the standards - instruction designed as a full instructional plan rather than a series of lessons

Circle the stage which best represents your current level of NGSS implementation:

Initial Exposure Deepening Understanding Planning Instruction Full Alignment

Have you had professional development training related to NGSS implementation?
____Yes______No

If yes, please estimate the number of hours of NGSS related professional development training you have had.
Number of hours __________

Please use the space below to provide any additional information that might help me further assess your current level of NGSS training or NGSS implementation stage.

Middle Level Science Teacher Perceptions of NGSS Survey

Please read each statement then mark the response that best represents your perspective. For these items 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, and 1 = Strongly Disagree

Statement	SA	A	N	D	SD
Seven Conceptual Shifts of the NGSS Interconnections in Science					
1. Science education must show real world interconnections in science.	**5**	**4**	**3**	**2**	**1**
2. The NGSS will help me construct curriculum that is deeply contextual.	**5**	**4**	**3**	**2**	**1**
3. The NGSS will help me teach students to apply scientific knowledge.	**5**	**4**	**3**	**2**	**1**
4. The performance expectations outlined in the NGSS will help me teach students in a way that demonstrates the relationship between scientific content, the practices of scientific inquiry, and engineering design.	**5**	**4**	**3**	**2**	**1**
Student Performance Expectations					
5. Science standards should represent student outcomes as opposed to curriculum.	**5**	**4**	**3**	**2**	**1**
6. The NGSS will guide me in constructing a creative and flexible curriculum.	**5**	**4**	**3**	**2**	**1**
7. The performance expectations outlined in NGSS will help me create coherent					

instructional programs that help students achieve the standards.	**5**	**4**	**3**	**2**	**1**
8. The performance expectations outlined in the NGSS will assist me in preparing students for assessments.	**5**	**4**	**3**	**2**	**1**
Learning Progressions					
9. Science concepts should build progressively across grade levels.	**5**	**4**	**3**	**2**	**1**
10. The NGSS will assist me in creating a curriculum that is focused.	**5**	**4**	**3**	**2**	**1**
11. The NGSS will assist me in creating a curriculum that is coherent.	**5**	**4**	**3**	**2**	**1**
12. Knowledge of curriculum that is implemented in grades below and above my own is essential to the success of an NGSS based curriculum.	**5**	**4**	**3**	**2**	**1**
Understanding and Application					
13. Science standards must focus on deeper understanding and application of content.	**5**	**4**	**3**	**2**	**1**
14. The focus of science standards should be on a small set of core ideas as opposed to facts and details associated with these core ideas.	**5**	**4**	**3**	**2**	**1**
15. Core ideas can provide a foundation for the acquisition of new knowledge.	**5**	**4**	**3**	**2**	**1**

16. The NGSS will help me teach students to learn and understand core principals and theoretical constructs as opposed to disconnected pieces of knowledge and isolated facts.	**5**	**4**	**3**	**2**	**1**
Science, Technology, and Engineering Integration					
17. Science and engineering must be integrated in science education.	**5**	**4**	**3**	**2**	**1**
18. The NGSS will assist me in creating curriculum which helps students think about how to address major world challenges.	**5**	**4**	**3**	**2**	**1**
19. The NGSS will assist me in creating curriculum which provides opportunities for students to use engineering and technology to deepen their understanding of science.	**5**	**4**	**3**	**2**	**1**
20. An NGSS based curriculum can help me empower my students to use what they learn in their everyday lives.	**5**	**4**	**3**	**2**	**1**
College, Careers, and Responsible Citizenship					
21. Science standards must prepare students for college, careers, and responsible citizenship.	**5**	**4**	**3**	**2**	**1**
22. The NGSS will assist me in teaching students that science and science education are central to the lives of Americans.	**5**	**4**	**3**	**2**	**1**

23. The NGSS will assist me in teaching students that science and science education are essential to the ability of the U.S. to continue to innovate, lead, and create future jobs.	**5**	**4**	**3**	**2**	**1**
Common Core Alignment					
24. Science standards must coordinate with Common Core Math and Language Arts Standards.	**5**	**4**	**3**	**2**	**1**
25. The NGSS will assist me in making science a part of students' comprehensive education.	**5**	**4**	**3**	**2**	**1**
26. The alignment of the NGSS with Common Core Standards will assist me in providing equitable access to learning standards for all students.	**5**	**4**	**3**	**2**	**1**

Please respond to the questions below.

Support for NGSS Implementation

What resources and/or supports will be most helpful to you in the implementation of the Next Generation Science Standards?

Challenges to NGSS Implementation

What challenges or barriers have you encountered or expect to encounter during the implementation of the Next Generation Science Standards?

Appendix E:

Middle School Teacher Interview Protocol

1. How long have you taught science?

2. What science subjects have you taught? Which do you currently teach?

3. What grade level do you currently teach?

4. In your opinion, what should be the current goal of science education?

5. How would you describe your level of familiarity with the Next Generation Science Standards (NGSS)?

Interconnections in Science

6. What do you feel is the purpose or the overall goal of the NGSS?

7. Do you believe that the NGSS will achieve this goal? Why or why not?

8. The performance expectations outlined in the NGSS are designed to help teachers teach students in a way that demonstrates the relationship between scientific content, the practices of scientific inquiry, and engineering design. Do you feel that the demonstration of this interconnection is important for students at the middle school level? Explain why or why not.

9. Have you implemented any lesson recently in which you have attempted to show the relationship between scientific content, the practices of scientific inquiry, and engineering design? Describe the lesson.

Student Performance Expectations

10. In your opinion, how should teachers of science use educational standards like the NGSS?

11. Do you feel that the NGSS will allow you the space to be creative and flexible in your teaching? What aspects of the standards gives you this impression?
12. Have the NGSS had any impact on the way you assess your students or how you plan to assess them in the future? Explain.

Learning Progressions

13. Do you feel that knowledge of curriculum that is implemented in grades below and above your own is essential to the success of an NGSS based curriculum? Explain why or why not.

Understanding and Application

14. In contrast to previous science education standards, the NGSS focuses on a small set of core ideas and deeper understanding and application of content. Do you feel this is appropriate for students at the middle school level?

Science, Technology, and Engineering Integration

15. How comfortable are you with incorporating technology into your science lessons?

16. How often do you assign students lesson that require technology?

17. How comfortable are you with incorporating engineering practices into your science lessons?

18. How often do you assign students lesson that require engineering design?

19. Have you facilitated lessons in which students have utilized both technology and engineering? Describe the lesson.

College, Careers, and Responsible Citizenship

20. Do you feel that an NGSS-based curriculum can help you empower your students to use what they learn in their science class in everyday life? Explain.

21. In your opinion, will the NGSS be adequate in helping middle school teachers prepare and guide middle school students on a path toward college, careers, and responsible citizenship? Explain why or why not.

Common Core Alignment

22. In your opinion, is it important that the NGSS coordinate with Common Core Math and Language Arts Standards? Why or why not?

Appendix F: EQuiP Rubric

EQuIP Rubric for Lessons & Units: Science

<u>Lessons *and* units</u> designed for the NGSS include clear and compelling evidence of the following:

I. NGSS 3D Design

The lesson/unit is designed so students make sense of phenomena and/or design solutions to problems by engaging in student performances that integrate the three dimensions of the NGSS.

A. **Explaining Phenomena/Designing Solutions**: Making sense of phenomena and/or designing solutions to a problem drive student learning.
   i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving.
   ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems.
   iii. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences.

B. **Three Dimensions**: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.
   i. Provides opportunities to *develop and use* specific elements of the SEP(s).
   ii. Provides opportunities to *develop and use* specific elements of the DCI(s).
   iii. Provides opportunities to *develop and use* specific elements of the CCC(s).

C. **Integrating the Three Dimensions:** Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.

II. NGSS Instructional Supports

The lesson/unit supports three-dimensional teaching and learning for ALL students by placing the lesson in a sequence of learning for all three dimensions and providing support for teachers to engage all students.

A. **Relevance and Authenticity**: Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world.
   i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations).
   ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate.
   iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience.

B. **Student Ideas:** Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and to respond to peer and teacher feedback orally and/or in written form as appropriate.

C. **Building Progressions**: Identifies and builds on students' prior learning <u>in all three dimensions</u>, including providing the following support to teachers:
   i. Explicitly identifying prior student learning expected for all three dimensions
   ii. Clearly explaining how the prior learning will be built upon

D. **Scientific Accuracy**: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.

E. **Differentiated Instruction**: Provides guidance for teachers to support differentiated instruction by including:
   i. Appropriate reading, writing, listening, and/or speaking alternatives (e.g., translations, picture support, graphic organizers, etc.) for students who are English language learners, have special needs, or read well below the grade level.
   ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations.
   iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.

III. Monitoring NGSS Student Progress

The lesson/unit supports monitoring student progress in all three dimensions of the NGSS as students make sense of phenomena and/or design solutions to problems.

A. **Monitoring 3D student performances**: Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.

B. **Formative:** Embeds formative assessment processes throughout that evaluate student learning to inform instruction.

C. **Scoring guidance**: Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.

D. **Unbiased tasks/items**: Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.

EQuIP Rubric for Lessons & Units: Science

Units designed for the NGSS will *also include* clear and compelling evidence of the following additional criteria:

I. NGSS 3D Design	II. NGSS Instructional Supports	III. Monitoring NGSS Student Progress
D. **Unit Coherence**: Lessons fit together to target a set of performance expectations. i. Each lesson builds on prior lessons by addressing questions raised in those lessons, cultivating new questions that build on what students figured out, or cultivating new questions from related phenomena, problems, and prior student experiences. ii. The lessons help students develop toward proficiency in a targeted set of performance expectations. E. **Multiple Science Domains**: *When appropriate*, links are made across the science domains of life science, physical science and Earth and space science. i. Disciplinary core ideas from different disciplines are used together to explain phenomena. ii. The usefulness of crosscutting concepts to make sense of phenomena or design solutions to problems *across science domains* is highlighted. F. **Math and ELA:** Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects.	F. **Teacher Support for Unit Coherence:** Supports teachers in facilitating coherent student learning experiences over time by: i. Providing strategies for linking student engagement across lessons (e.g. cultivating new student questions at the end of a lesson in a way that leads to future lessons, helping students connect related problems and phenomena across lessons, etc.). ii. Providing strategies for ensuring student sense-making and/or problem-solving is linked to learning in all three dimensions. G. **Scaffolded differentiation over time**: Provides supports to help students engage in the practices as needed and gradually adjusts supports over time so that students are increasingly responsible for making sense of phenomena and/or designing solutions to problems.	E. **Coherent Assessment system:** Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning. F. **Opportunity to learn**: Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback.

Appendix G: Middle Level Science Teacher Perception Survey Responses

Table 6

Participant Survey Responses to Questions about Interconnections in Science

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science education must show real-world interconnections in science.	80%	20%	-	-	-
The NGSS will help me construct a curriculum that is deeply contextual.	33.3%	53.3%	13.3%	-	-
The NGSS will help me teach students to apply scientific knowledge.	60%	40%	-	-	-
The performance expectations outlined in the NGSS will help me teach students in a way that demonstrates the relationship between scientific content, the practices of scientific inquiry, and engineering design.	46.7%	53.3%	-	-	-

Table 7

Responses to Questions about Student Performance Expectations

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science standards should represent student outcomes as opposed to **curriculum**.	50%	42.9%	7.2%	-	-
The NGSS will guide me in constructing a creative and flexible curriculum.	13.3%	46.7%	40%	-	-
The performance expectations outlined in NGSS will help me create coherent instructional programs that help students achieve the standards.	20%	60%	20%	-	-
The performance expectations outlined in the NGSS will assist me in preparing students for assessments.	20%	60%	20%	-	-

Table 8

Responses to Questions about Learning Progressions

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science concepts should build progressively across grade levels.	60%	40%	-	-	-
The NGSS will assist me in creating a curriculum that is focused.	20%	66.7%	13.3%	-	-
The NGSS will assist me in creating a curriculum that is coherent.	21.4%	50%	28.6%	-	
Knowledge of curriculum that is implemented in grades below and above my own is essential to the success of an NGSS based curriculum.	53.3%	46.7%	-	-	-

Table 9

Responses to Questions about Understanding and Application

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science standards must focus on deeper understanding and application of content.	60%	33%	6.7%	-	-
The focus of science standards should be on a small set of core ideas as opposed to facts and details associated with these core ideas.	40%	46.7%	13.3%	-	-
Core ideas can provide a foundation for the acquisition of new knowledge.	33.3%	60%	6.7%	-	-
The NGSS will help me teach students to learn and understand core principals and theoretical constructs as opposed to disconnected pieces of knowledge and isolated facts.	40%	46.7%	13.3%	-	-

Table 10

Responses to Questions about Science, Technology, and Engineering Integration

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science and engineering must be integrated **in** science education.	80%	13%	6.7%	-	-
The NGSS will assist me in creating **curriculum** that helps students think about how to address major world challenges.	53.3%	26.7%	20%	-	-
The NGSS will assist me in creating curriculum which provides opportunities for students to use engineering and technology to deepen their understanding of science.	66.7%	26.7%	6.7%	-	-
An NGSS based curriculum can help me empower my students to use what they learn in their everyday lives.	53.3%	40%	6.7%	-	-

Table 11

Responses to Questions about College, Careers, and Responsible Citizenship

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science standards must guide teachers in preparing students for college, careers, and responsible citizenship.	80%	13.3%	6.7%	-	-
The NGSS will assist me in teaching students that science and science education are central to the lives of Americans.	46.7%	40%	13.3%	-	-
The NGSS will assist me in teaching students that science and science education are essential to the ability of the US to continue to innovate, lead, and create future jobs.	46.7%	40%	13%	-	-

Table 12

Responses to Questions about Common Core Alignment

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Science standards must coordinate with Common Core Math and Language Arts Standards.	20%	53.3%	20%	6.7%	-
The NGSS will assist me in making science a part of students' comprehensive education.	40%	53.3%	6.7%	-	-
The alignment of the NGSS with Common Core Standards will assist me in providing equitable access to learning standards for all students.	26.7%	46.7%	26.7%	-	-