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Implementing Elementary School Next Generation Science Standards

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This is to certify that the doctoral dissertation by

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2017

Abstract

Implementing Elementary School Next Generation Science Standards

by

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MS, Baylor University, 1993

BS, Siena College, 1991

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Implementation of the Next Generation Science Standards requires developing elementary teacher content and pedagogical content knowledge of science and engineering concepts. Teacher preparation for this undertaking appears inadequate with little known about how in-service Mid-Atlantic urban elementary science teachers approach this task. The purpose of this basic qualitative interview study was to explore the research questions related to perceived learning needs of 8 elementary science teachers and 5 of their administrators serving as instructional leaders. Strategies needed for professional growth to support learning and barriers that hamper it at both building and district levels were included. These questions were considered through the lens of Schön’s reflective learning and Weick’s sensemaking theories. Analysis with provisional and open coding strategies identified informal and formal supports and barriers to teachers’ learning. Results indicated that informal supports, primarily internet usage, emerged as most valuable to the teachers’ learning. Formal structures, including professional learning communities and grade level meetings, arose as both supportive and restrictive at the building and district levels. Existing formal supports emerged as the least useful because of the dominance of other priorities competing for time and resources. Addressing weaknesses within formal supports through more effective planning in professional development can promote positive change. Improvement to professional development approaches using the internet and increased hands on activities can be integrated into formal supports. Explicit attention to these strategies can strengthen teacher effectiveness bringing positive social change.

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Dedication

I dedicate this work to the memory of my father, Brendan K. Hynes, whose love and encouragement will always be with me. My parents, Brendan and Anne, have always exemplified hard work, dedication, and a sense of faith, service, and commitment that I can only try to emulate. I try each day to live as they have and to model their values to my own children.

I dedicate this achievement to my husband Brian and my sons, James, Will, Colin, Owen, and Shane. Your support and encouragement inspired me every day to never give up and to believe in myself. Without the unfaltering faith and support on the part of my husband, I would never have taken the first steps of this journey. Your love and support has made all the difference. Thank you!

"So many of our dreams at first seem impossible, then they seem improbable, and then, when we summon the will, they soon become inevitable."– Christopher Reeve

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Table of Contents

List of Tables iv

Chapter 1: Introduction to the Study 1

Background 4

Problem Statement 6

Purpose of the Study 8

Research Questions 8

Conceptual Framework 8

Nature of the Study 9

Definitions 10

Assumptions 11

Scope and Delimitations 11

Limitations 12

Significance 12

Summary 14

Chapter 2: Literature Review 16

Literature Search Strategy 18

Conceptual Framework 19

Literature Review 21

Teacher Learning 22

Organizational Support of Learning 24

Pedagogical Content Knowledge 29

Science ... 31
Engineering ... 33
STEM Integration ... 37
Elements of Professional Development ... 39
Summary and Conclusions ... 43
Chapter 3: Research Method ... 46
Research Design and Rationale ... 46
Role of the Researcher ... 48
Participant Selection ... 50
Instrumentation ... 53
Procedures for Recruitment, Participation, and Data Collection ... 54
Recruitment ... 55
Participation ... 55
Data Collection ... 56
Data Analysis Plan ... 57
Issues of Trustworthiness ... 59
Ethical Considerations ... 60
Summary ... 61
Chapter 4: Results ... 62
Setting ... 63
Demographics ... 64
Data Collection ... 66

Data Analysis 71
Evidence of Trustworthiness 76
Credibility 76
Dependability 77
Transferability 77
Results 79
Research Question 1 83
Sub-Question 1 89
Sub-Question 2 99
Research Question 2 107
Summary 116
Chapter 5: Discussion, Conclusions, and Recommendations 121
Interpretation of the Findings 122
Limitations of the study 130
Recommendations 131
Implications 134
Conclusion 136
References 138
Appendix: Interview Prompts 152

List of Tables

Table 1. Participant Demographics.. 666

Table 2. Emergent Themes and Categories……………………………………………...82

Chapter 1: Introduction to the Study

The Next Generation Science Standards (NGSS Lead States, 2013) signify the most recent effort by policy makers to support the improvement of student achievement and increase scientific literacy in the United States. The foundational changes advocated within the Next Generation Science Standards (NGSS) embody the modifications designed to have the instruction of science and engineering mirror the manner in which scientists and engineers approach the everyday processes of working within their respective fields. These changes reflect a three dimensional approach to authentic practice with an emphasis on discipline knowledge, cross cutting concepts, and science and engineering practices (NGSS Lead States, 2013). These standards build on the progressions encompassed within the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) and the National Science Education Standards (National Research Council, 1996). Using findings from research in the areas of teaching and learning over the last 20 years also informed the development of the NGSS and its underlying framework.

The creation of the framework for K-12 science education (National Science Teachers Association, 2013) resulted from the collaborative efforts of 26 lead states, The National Science Teachers Association, and Achieve. It reflects the most accurate understanding of teaching and learning within science and engineering. The NGSS mirror the vision embodied within the framework and provide measures that promote student engagement through science and engineering practices in the pursuit of understanding disciplinary concepts and unifying themes across domains (National Science Teachers Association, 2013).

As noted by the National Research Council (2012) and others (Wilson, 2013; Keeley, 2005), to best implement these changes, classroom teachers will be required to have an understanding of not only the content knowledge specific to particular domains such as life science, earth and space systems, physical science, and engineering but also to have a sufficient foundation to recognize the authentic practices within these fields. Together with these requirements, teachers should have knowledge of the connections that support continuity across each of the disciplines. Strengthening instructional and pedagogical content knowledge of both science and engineering has been identified as a need at local, state, and national levels (National Research Council, 2011). Support for learning the science content and pedagogical approaches for teaching science and engineering is a need within the elementary teacher population (National Academies, 2015).

Current reform efforts to improve education involve supporting teacher development with the intent of increasing student achievement (Marion & Gonzales, 2014; Senge, 2012). Facilitating effective implementation of these reform efforts requires developing content and pedagogical content knowledge of practicing teachers at all grade bands (Perkins & Reese, 2014). Recent case studies have provided insight into how different populations of teachers as well as students have benefited from professional learning support with varied time spans and with wide-ranging content foci (Allen & Penuel, 2014; Lehman, Kim, & Harris, 2014; Schneider & Plasman, 2011). Providing effective professional development support for in-service teachers within districts is a crucial feature of enhancing student achievement among the fields of science, technology, engineering, and mathematics education, also known as STEM fields (Fullan, 2012; Marion, 2014; Poekert, 2012; Senge, 2012).

The understanding of how teachers develop and deepen their conceptions of science and engineering concepts was lacking (Daugherty & Custer, 2012; Ireland, Watters, Brownlee, & Lupton, 2012) and was the topic of this research. Educators currently working with students in the classroom must increase their own comprehension of science and engineering concepts. This is particularly true of the engineering design process construct, which was prominently featured in the NGSS (2013). Teachers were also charged with increasing their own pedagogical content knowledge to implement NGSS reforms. Pedagogical content knowledge, as argued for by Shulman (1987), expresses how teachers reflect on and interpret subject matter and then how the teachers determine how it should be organized and presented through instruction for the specific characteristics of the student population they are working with. Little was known about how teachers identify and describe learning experiences needed to help them increase their content knowledge and pedagogical content knowledge. How administrators describe the needs for teachers learning new science and engineering content and pedagogical content was also poorly illustrated in the literature. This research addressed this gap within the literature. Enhancing teacher learning and supporting student achievement remains a complex issue that has an impact upon many levels of society.

The learning needs were viewed in this study as approaches to facilitate new learning and assistance needed to overcome barriers as perceived by the teachers to enhance their content and pedagogical content knowledge of science and engineering. Support of this learning into classroom practice was explored as the application of learning. The needs of the district and of the individual teachers as professionals are described in the results section from the perspectives of building and district level leadership. Examples of these leadership positions included administrators such as principals and science supervisors. The perceptions of these instructional leaders were also explored and compared to the self-reported learning needs of the elementary teachers. The mechanisms that support learning of new content and pedagogy are described in the results section from these different viewpoints.

This chapter is arranged to present the background, problem statement, and nature of the study. Each section offers relevant information to the context of the study to address the research questions. The chapter continues with the definitions, assumptions, and scope and delimitations as well as limitations of the study. The chapter concludes with specific attention to the possible significance of the investigation and its findings potential influence on social change.

Background

National, state, and local appeals for education improvement are influencing policies and programs for both students and teachers. Increasing student success remains a national interest, and as President Barack Obama noted, “ We must comprehensively strengthen and reform our education system in order to be successful in a 21st century economy" (U.S. White House, 2012). The National Research Council (NRC) used evidence-based research to reveal a strong link between teacher capability and increasing student achievement (NRC, 2000). Teacher expertise is underpinned by a deep foundational understanding in both content and pedagogical content knowledge as noted by No Child Left Behind (2002). Building on established links between student accomplishment and instructor expertise, plans to advance teacher growth should be based on evidence-based approaches that strive to augment educator effectiveness.

Educators have been challenged to react to advancements in the NGSS (NGSS Lead States, 2013). The criteria of these new benchmarks make use of a three dimensional approach to science with explicit attention to the components of authentic practice, cross cutting concepts integrating various science domains, and disciplinary core ideas. One substantial change from previous policy or reforms is the incorporation of engineering into the science framework. Teacher preparation programs at the elementary level are lacking in that they do little to prepare today's teachers to work in the modern classroom setting with greater student diversity and the growing challenge to promote 21st century skills in science and engineering (NRC, 2005; State of New Jersey Department of Education, 2014).

Professional development concentrating on elementary level teacher learning of engineering content and practices that would enhance pedagogical content knowledge has not progressed greatly. While related inquiries addressed the modifications in content expertise of secondary level teachers, the manner in which this change comes about or transforms classroom procedures within other grade bands has not been thoroughly investigated (Daugherty & Custer, 2012; Patricia, Nanny, Refai, Ling, & Slater, 2010). The transfer of teacher learning into effective practice requires educators to consider their own level of content and pedagogical content knowledge and identify gaps between their understanding and expectations found within new standards (NRC, 2005). Mechanisms to bridge these gaps in knowledge and practice and understanding teacher perceptions of this process are a growing field in teacher learning research.

Exploring these topics may support programs for improved teacher knowledge and practice and ultimately, student achievement. Promoting transformations within instructional approaches will involve understanding teacher learning needs, which stands at the center of enhancing practice. Essential elements of teacher skills develop on a framework that builds content understanding as well as pedagogy and concentrates on learning progressions and an understanding of student thinking (American Association for the Advancement of Science, 1993, 2001; NGSS Lead States, 2013; NRC, 1996; Keeley, 2005; Wiggins & McTighe, 2005). Gains in these areas are an important consideration for individuals and groups focused on teacher learning and supporting the successful implementation of standards such as the NGSS.

Problem Statement

Although prior researchers have analyzed secondary level teachers for changes in their content knowledge of engineering, the mechanisms that supported these changes or how this deeper understanding may translate into classroom practices at the elementary level has not been thoroughly examined (Daugherty & Custer, 2012; Patricia et al., 2010). The support mechanisms examined to facilitate teacher learning included informal supports such as individual approaches to learning through online resources or collaborations and formal strategies such as professional learning communities, workshops, and formal coursework. Such research focused on elementary teacher is lacking. Supporting teachers at all levels of instruction is essential to facilitate student learning in each subject area. Elementary teacher content knowledge in science and engineering was weak as compared to preparedness in other subject areas. The NRC (2010) examined teacher preparation programs and determined that on average, participants in elementary certification programs received only 13 credit hours in the areas of science or engineering during their formal training.

Fostering a stronger foundation of science content knowledge and pedagogical content knowledge for practicing teachers at the elementary level of Kindergarten to sixth grade is necessary and therefore critical to effective programs that support student achievement. While there are a variety of supports available to elementary teachers to facilitate their learning, teachers may value these mechanisms differently based on past experiences with professional learning and the perceived effectiveness of these supports. Consequently, it is necessary to understand what teachers and administrators believe are the needed support measures to improve science and engineering understanding of teachers delivering NGSS. An examination of the structures, both in regard to formal and informal mechanisms, is required. Teachers engage in these structures during the professional learning experiences that are supposed to be designed to increase content and pedagogical content knowledge of science and engineering concepts. It is imperative that the needs of elementary school teachers and the strengths and weaknesses of the supports available be known so that the demands of the NGSS can be met.

Purpose of the Study

The purpose of this qualitative interview study was to explore in-service elementary teacher and administrators' perceptions of what constitutes supports and barriers to facilitate their own learning of novel science and engineering concepts and pedagogical learning in a mid-Atlantic urban school setting of the United States. The unit of analysis was with teachers and building administrators.

Research Questions

Research Question 1: How do elementary teachers perceive their needs for learning new science and engineering content knowledge and acquiring pedagogical content knowledge for teaching in response to NGSS reforms?

Subquestion 1. What strategies do elementary teachers perceive would provide support for learning new content and developing pedagogical content knowledge?

Subquestion 2. What do elementary teachers perceive are the barriers and challenges to learning new content and pedagogical content knowledge regarding NGSS?

Research Question 2: What do administrators believe are the barriers and challenges to the implementation of mandated NGSS?

Conceptual Framework

The construct of adult learning characterizes that the potential for new knowledge and understanding takes place when a disruptive experience transpires and the individual becomes aware that there is a gap in his or her own understanding. The recognition that there was a need for additional knowledge becomes the catalyst for learning. Weick (1995) elaborated on this notion of Schön's (1983) reflective learning through a process termed sensemaking. Weick depicted the extension of reflective learning through a lens that connects the process of producing context for new information and its relation to existing understanding. An in-depth explanation of these frameworks and their connections can be found in Chapter 2.

The lens of reflective learning and sensemaking provided the framework to explore how K to 6 teachers continue and approach their own learning while in a classroom setting. This framework also addressed the notions of why the learning is occurring. Shifts in the standards and revisions in the curriculum are expected to prompt disruptive events and sensemaking opportunities for educators as individuals as well as that of a collaborative group as they design for and employ new content in their classrooms with the goal of enhancing student achievement. An increased understanding of this mechanism from the point of view of the teacher through the collection and analysis of data within this research study may contribute to the field of adult learning.

Nature of the Study

In this qualitative interview study, I explored eight teachers' and five administrators' beliefs concerning the learning needs that arise based upon responses to the NGSS. The research design was strengthened with the framework of adult reflective learning (Schön, 1987; Weick, 1995). The inquiry described the learning needs within science and engineering domains of elementary teachers who were responding to shifts in standards and curriculum based on policy reform.

Participants were recruited and selected with intensive purposeful sampling strategies of elementary teachers. Semistructured interviews were designed to capture desired data within the study. Interviews of administrators provided information for triangulation as well as evidence from implementation. Provisional and open coding schemes were applied for the identification of categories and themes. Building on the theories of Schön (1987) and Weick (1995), factors influencing adult learning supported the analysis methodology.

Definitions

Administrator: For the purpose of this study, administrators were defined using Abbott's (2014) definition as individuals such as principals who manage school operations and coordinate curricula, oversee teachers and other school staff, and facilitate the learning environment for students.

Content knowledge: The body of knowledge associated within the field of science and engineering including facts, concepts, and theories. This includes the disciplinary knowledge of life, physical and earth and space science as well as of the engineering design process. Students are expected to understand content knowledge associated with a particular area after instruction (Abbott, 2014).

*Elementary teacher***:** Teachers at the elementary level were defined for this study as being employed as full time staff in a Kindergarten through Grade 6 school (Golding, Gray, & Bitterman 2013).

Next Generation Science Standards (NGSS): Science standards that are focused on practices, content, and connections across domains; the NGSS were created based on the framework for K-12 science education from the NRC (2011). Development was led by states as well as education stakeholders, including scientists, education researchers, teachers, and industry leaders.

Pedagogical content knowledge: Based on Shulman (1986), pedagogical content knowledge describes the ways of representing phenomena to increase understanding to others. This may include models and demonstrations. A key feature of pedagogical content knowledge is the knowledge of what makes topics easy or challenging to learn for different audiences.

Assumptions

It was assumed that participants answered the interview questions honestly and accurately and that each participant who is currently an elementary teacher teaches science as part of his or her grade level responsibilities. It was also assumed that administrators served as instructional leaders within the school, support school operations, and oversee staff development. Working under these assumptions facilitated exploring the phenomena in question: teacher and administrators' perceptions regarding their preparation in science and engineering to respond to NGSS.

Scope and Delimitations

The exploration in this research was bound to the distinctive features of the target population—full time elementary teachers and administrators who provided instruction on science and engineering and were responding to the expectations of NGSS. The particular aspects of teacher perceptions for the need and facilitation of ongoing learning served as the focus points to gain a deeper understanding of mechanisms to respond to new learning challenges based on standards reform. The framework of reflective learning and sensemaking determined the boundaries of the exploration in relation to ongoing adult learning of an elementary classroom teacher in the areas of science and engineering. Insights from the study may be transferable to similar elementary teacher populations.

Limitations

The study was limited to the constraints of the population examined. Replicable application beyond the sample population may be limited. This study was also limited to responses to the NGSS by the participants and did not address other standards or reforms. The timeline for implementation of the NGSS was also an identified limitation. The expectation by district administration, in parallel with State Department of Education guidelines, was for instruction to be aligned with the new standards at the elementary level for the fall of 2017. The expectations within the district could create bias among the participants and were addressed with follow up questions within the interviews.

Significance

Responding to the shifts promoted within the NGSS (Achieve, 2013) thrusts many teachers into a position where they need to enhance both their content knowledge as well as their pedagogical content knowledge in order to facilitate science and engineering instruction in the elementary classroom. How these shifts are productively integrated for teachers somewhat depends on teachers' perceptions of needs and challenges associated with increasing one's own proficiency. Describing how teachers perceive their needs in regard to the expectation to teach science and engineering constructs and describing how administrators perceive teacher needs, as attempted in this study, could create a significant step towards strengthening professional development for teachers. If it is possible to better understand and integrate the self-identified needs of teachers into professional development strategies, it might create the potential for increased teacher scholarship. Teacher quality and expertise have a direct impact on student achievement (NRC, 2010), and, therefore, supporting teacher growth remains an objective at local, state, and national levels (U.S. White House, 2012). The results of this study may assist in that support.

Consequently, supporting elementary teachers through the changes and additions found within the NGSS with a clear sense of their learning needs could ultimately support student achievement. Recommendations that emerged from this study for professional learning experiences that engage teachers with learning approaches they themselves have identified as effective can increase the effectiveness of the professional development experience. Enhancing professional development may support positive social change.

Effective use and application of the NGSS was expected to create an opportunity to improve science education and enhance student achievement (Marion, 2014; Poekert, 2012). Supporting the transformation of instructor knowledge and practice, at a meaningful level, can promote positive social change in that it can lead to a deeper understanding of how teachers learn. Results of this study may be of interest to both individual teachers and leadership in their attempts to provide professional development for teacher learning and growth.

Summary

This chapter provided an introduction and context for the study through a discussion of the current issues facing elementary teachers responding to NGSS reform mandates and the need to further understand their experiences with those mandates. The NGSS represent a change in how science and engineering are expected to be taught in elementary classrooms. Practicing teachers may not have the content background in science or engineering to facilitate these new concepts or the pedagogical understanding to effectively facilitate instruction in the classroom. As described in the problem statement, elementary teachers have been asked to learn these concepts as practicing teachers through various professional development experiences.

Little was known about how elementary teachers or administrators describe teacher learning needs to enhance content and pedagogical content knowledge of science or engineering that is aligned with changes associated within the NGSS. The purpose of this qualitative interview study was to understand the perceptions of the learning needs of elementary teachers in relation to the mechanisms that are available to promote both content knowledge of science and engineering concepts and the pedagogical content knowledge to use strategies to implement NGSS into their classrooms. These mechanisms included both formal and informal strategies that teachers rely on to support professional learning. The conceptual framework of adult learning, as viewed through the work of Schön (1987) and Weick (1995), provided the lens to view these needs. Reflective learning and sensemaking make visible how adults view their learning experiences in response to change such as the NGSS. A deeper understanding of elementary teacher learning needs and the perceptions of administrators of these learning needs could therefore promote social change by informing professional development planning to strengthen teacher effectiveness and ultimately student achievement.

Chapter 2 provides a detailed examination of current work within the field, exploring the present state of both teacher and student learning of science and engineering. Contrasting approaches and goals provide insight into the emerging areas of research within adult learning and give attention to the particular challenges associated with identifying and meeting the needs of facilitating teacher learning within the STEM fields.

Chapter 2: Literature Review

There was a need for increased understanding of what elementary teachers and administrators perceive was required for them to increase learning content and pedagogical content knowledge of science and engineering concepts at the elementary level to meet NGSS. The purpose of this qualitative interview study was to explore in-service elementary teacher and administrators' perceptions of what constitutes supports and barriers to facilitate their own learning of novel science and engineering concepts and pedagogical learning in a mid-Atlantic urban school setting of the United States.

Science instruction had been changing at all levels within the K-12 system. The NGSS represent a shift in the manner in which science and engineering were to be taught to more accurately reflect the approach used by scientists and engineers (NGSS Lead States, 2013). The NRC (2011) identified the need at the local, state, and national levels to increase content and pedagogical content knowledge in teachers implementing these new standards. Perkins and Reese (2014) determined that effective implementation of the reform strategies framed within the NGSS required enhancing both content and pedagogical content knowledge for teachers at all grade levels. Additional case study research highlighted that unique approaches to professional learning experiences of mixed durations and content foci supported teacher and student achievement for diverse participant groups (Allen & Penuel, 2014; Bassiker, 2014; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Lehman et al., 2014; Schneider & Plasman, 2011). However, agreement as to how teachers develop an understanding of engineering concepts found within the NGSS is lacking (Daugherty & Custer, 2012; Ireland et al., 2012). Facilitating this understanding with the larger goal of promoting student achievement is critical within the area of STEM education (Bassiker, 2014; Lehman et al., 2014; Poekert, 2012; Senge, 2012).

The emphasis on promoting education within the disciplines of STEM extended as well to national interests to remain competitive (Allen & Penuel, 2014; Purzer, Strobel, & Cardella, 2014; Wang, Moore, Roehrig, & Park, 2011). Increased employment opportunities in a global knowledge economy depend upon the understanding of disciplines within each STEM field (NRC, 2011). The technologically-based information systems that are cornerstones of a 21st century economy require a deeper understanding and application of mathematics and science thinking (Moore et al., 2014).

Adding to the understanding of this challenge, Bissaker (2014) noted that declining engagement in STEM areas was linked to not only negative student attitudes and a perception of the irrelevance of the curriculum but to an inadequate number of qualified STEM teachers. Developing the qualifications of teachers within STEM areas emerged as a need and area of research. Supporting teachers to develop expertise for the purpose of increasing student interest and achievement in STEM fields has been a priority within many programs for preservice and in-service teachers (Wang et al., 2011). Engineering serves as an effective entry point to motivate student learning in mathematics and science as well as technology (Stohlmann, Moore, & Roehrig, 2012). The integration of engineering content within science as framed within the NGSS may serve as a mechanism to address deficiencies in mathematics and science disciplines and add depth to the STEM fields.

This chapter includes an evaluative analysis and then a synthesis of the relevant literature on teacher learning with a specific focus on technical scholarship and its presence within curricula encompassing STEM. First, using the literature review, I synthesized themes based on current findings that highlighted the existing state of science education reform and teacher training, with a focus on elementary grades. The focus on supporting teacher learning in response to reforms put forth by measures such as the NGSS provided a lens to examine research within the field. Results that highlighted the relevant learning theories of Schön (1987), reflective learning, and Weick (1995), sensemaking, provided a context to evaluate the effectiveness of the research examining changes in content and pedagogical content knowledge for teachers within diverse settings. Findings from applicable studies were used to evaluate the current state of teacher learning and the unique needs of developing understanding within science and engineering. These results were seen through the lenses of reflective learning and sensemaking and were viewed as a measure for instructors to be prepared to effectively implement the NGSS.

Literature Search Strategy

Key search terms are identified to focus the literature review. Descriptors such as *science learning*, *engineering learning*, *teacher learning*, *pedagogical content knowledge*, *reflection*, *STEM integration*, *elementary teacher learning*, *secondary teacher learning*, *implementation of reform*, and *STEM learning* were used to review the libraries at Walden University and the Stevens Institute of Technology. They were also used in search engines such as Google scholar and databases including ERIC and

EBSCO. Extensive searches to identify elementary teacher learning needs within science or engineering yielded few studies that address perceptions of needs or the learning needs of in-service teachers, thus identifying a gap in the literature.

Conceptual Framework

Developing content and pedagogical content knowledge of classroom teachers requires an understanding of the characteristics and needs of adult learners. Schön's theory (1983, 1987), reflection in knowledge, provides the lens to examine how teachers describe their own learning experience. Weick (1995) built on reflective learning in his theory of sensemaking, which considers how learning may take place within an organizational setting such as a school. Consideration of variables including characteristics of adult learners, unique features of science and engineering concepts, and current professional development approaches can be enhanced by a deeper understanding of the perceived learning needs of in-service teachers.

Schön's (1987) position on learning centers on the belief that learning is a continuous endeavor for both individuals and for the larger society. The impetus for learning is described as a disruptive event. This event occurs when there is an awareness or challenge to an individual's assumptions or understanding or to their frame of reference. When this occurs, the situation is characterized as unique and learning takes place. Schön described the role of reflection in learning in that an experience occurs, a response is given within the moment, and reflection occurs after the response as a way to process the event and new information. Through this lens, there is no one way to approach learning.

Farrell’s (2012) description of this sequence of learning for the teacher within the classroom highlights the significance of the classroom setting as a learning environment. There is a spontaneous response of a disruptive event within the classroom, and an unusual response from a student will generate surprise from a teacher who must reflect on his or her own understanding to reconcile the information. The teacher will employ a “reflection-in-action” response to meet the needs of the student; this artistry is often referred to as thinking on your feet within education. This action and reflection will deepen the understanding of the teacher while supporting the student.

Weick’s (1995) work with sensemaking is an extension of reflection involved in learning and is applied to a larger population or organization. Characteristics of sensemaking include having a new event, retrospection on the activities, and social contact to further develop understanding. Sensemaking can also be thought of as placing ideas into a framework or constructing meaning to deepen understanding. Within a group setting, leadership may help provide sense for the group, by providing clarification and direction. As organizations process new circumstances, sensemaking can be an effective strategy to ensure organizational movement in the same direction.

Sensemaking deepens understanding in that as ideas are put into a framework, they help to develop the prior definitions within the frameworks (Weick, 1995). There is attention to the process, and reflection is a required element of this process. Sensemaking is an effective organizational approach to policy changes that may bring about novel practices or content to a school system.

Prior researchers have examined secondary teacher changes in the understanding of engineering concepts, but evidence of the translation of understanding into classroom practice is lacking (Daugherty & Custer, 2012; Patricia et al., 2010). Evidence into changes in elementary teacher comprehension of engineering concepts specifically is also poorly understood. Stohlmann et al. (2012) reported that STEM integration, regarded as a relatively new instructional approach, has limited research describing teacher skill, beliefs, or understanding of needed content understanding. Stohlman et al. claimed that "the best way in which to attract, train, and retain qualified teachers remains to be answered" (p. 28). Considering the generalist background of teachers, deeper understanding of elementary teacher learning needs is necessary to inform professional development strategies and implementation plans of the NGSS in a meaningful way. The framework of reflective learning is an appropriate approach to examine these phenomena and facilitated both the development of the interview questions for data collection as well as the analysis approach to the responses of the questions.

Literature Review

In this literature review of evidenced-based findings from peer reviewed journals, I examined variables that have an impact upon the successful implementation of science education reform such as the modifications outlined in the NGSS (NGSS Lead States, 2013). Studies within the previous 5 years outline the current state of the science and engineering education fields in regard to teacher learning through various perspectives. Influences on the integration of the related fields of STEM into classroom practice are also contemplated in regard to supporting teacher learning. Factors including strategies to enhance content and pedagogical content knowledge trends to effective professional development approaches provided a frame from which identifying teacher learning needs can be examined in light of science and engineering.

The organization of this literature review follows a format that outlines the current state of scholarship in the following areas: (a) teacher learning, (b) organizational support of learning, (c) reflection, (d) pedagogical content knowledge, (e) science content knowledge, (f) engineering content knowledge, (g) STEM integration, and (h) effective professional development. Studies were reviewed to identify the status and key themes within the disciplines. The existing circumstances of variables that have an impact upon teacher learning within the arena of STEM were identified and relevant findings are presented.

Teacher Learning

The NRC (2015) advocated for multiyear professional development plans to support the rigorous cognitive demands that transitioning to the NGSS will require for current school practitioners. Elementary classroom teachers in particular require support to develop both science and engineering expertise needs that reflect the NGSS approach. This move highlighted the intersection of practices, content, and cross cutting concepts that reflect the real world application of these fields. Improving education depends on the effective implementation of reforms, and teacher development is its cornerstone and necessity (Liu, Carr, & Strobel, 2012). Teacher preparation programs do not require a uniform approach to science certification. As noted by the NRC (2010), pathways for certification vary between institutions, and background variability exists among certified teachers. This is challenging for elementary teachers who often have two laboratory science courses in their formal training yet will be expected to address topics in life, physical, Earth, and space science, with engineering integrated throughout the units (NRC, 2010).

At present, at least 41 states have developed or adopted curriculum standards that include engineering that is integrated beginning at the elementary level (Carr, Bennett, & Strobel, 2012.). Wilson-Lopez and Gregory (2015) reported that many elementary teachers are not comfortable teaching engineering. Demands on instructional time and uncertainty of the subject matter contribute to this issue. Reforms such as the NGSS, however, require that elementary students can and should develop skills and competencies that are rooted in the engineering field (Wilson-Lopez & Gregory, 2015).

Existing learning progressions and national standards are in place to support teacher development and practice, but researchers have indicated that these frameworks do not translate into classroom practice (Keeley, 2005; NRC, 2000). The adult reflective learning theories of Schön (1983) and Weick (1995) frame the examination of the development of content knowledge for practicing teachers as individuals and as communities of change within the school setting. The changing landscape of teaching in regard to content knowledge within science and engineering contributes to the difficulty in teaching. These changes necessitate ongoing professional learning and support for classroom teachers to transform their classrooms (Danielson, 2015).

Organizational Support of Learning

Continuous learning for classroom teachers will require support at the school level to promote individual and systemic change. DuFour and Fullan (2013) identified conditions that support learning and promote organizational change—engagement of the individual teacher and the approach to learning that is created within the work environment. These conditions may overlap with what teachers or administrators describe as necessary to promote learning for individual teachers.

Engagement. The connection of learning activities with what is considered an essential part of the job is needed to enhance learning. DuFour and Fullan (2013) termed this as learning that is *job embedded*. Relating the learning to what occurs every day in the classroom is thought to promote ongoing learning. It is important that learning activities are not viewed as additional or add on requirements but will support the day-to-day mission of the teacher within the classroom. Learning new concepts is also more effective if facilitated through an active manner, not passively transmitted to teachers.

Approach to learning. The explicit communication of learning goals for the teachers within the class and across grades is necessary to support individual and systemic growth. DuFour and Fullan (2013) advocated for this articulation to promote systemic change. The National Academies of Science, Engineering, and Medicine (2015) have identified group learning as desired for teachers who are developing an understanding of science concepts in the NGSS. This approach would be reflected in the NGSS through the articulation of performance expectations that are described within the new standards. Within the building, there would be clear communication of the progression of science and engineering concepts across grade levels. Diffusion of learning among teachers would also be facilitated within groups by involving teams or groups of teachers and not expecting teacher growth to occur in isolation. DuFour and Fullan noted group learning as a necessary condition to support growth. Teachers and administrators will use student learning outcomes that are articulated in the NGSS as the mechanism to evaluate growth for teachers within the building.

Supporting learning will require support at both the individual and organizational level. Responding to the rapidly changing knowledge-based economy that today's students must compete in necessitates that teachers be continually prepared. These changes are necessary and difficult (DuFour & Fullan, 2013). Defining the issues within the context of practice reflects Schön's (1987) view of learning and the theory of sensemaking that builds on this within the arena of organizations. How organizations support teacher learning, especially in regard to engineering and STEM integration exemplifies the sensemaking process of defining boundaries to promote change.

As Weick (1995) emphasized in his work describing sensemaking, the process creates a framework and constructs understanding through mutual patterning and comprehending. This process is needed to allow teachers and organizations to transition into a zone of comfort and confidence, enabling the effective implementation of NGSS. Allen and Penuel (2014) investigated how the organizational culture present influences the impact of professional development experiences. Emergent findings highlighted uncertainty and ambiguity as key factors that limit effective implementation of concepts introduced during professional development experiences. The most successful participants used colleagues within their local educational contexts to help with the processing and reconciliation of professional development goals and district priorities.

The ability of individuals in leadership positions to support teacher learning is affected by the awareness and understanding of the disciplines themselves. Few administrators can accurately define STEM education and therefore concerns for appropriate support for teacher learning and meaningful implementation of STEM within schools exists (Brown, Brown, Readon & Merril, 2011). Brown et al., (2011) advocated for an increased awareness for both teachers and administrators to address the lack of understanding that contributes to poor STEM integration within schools at the present. Facilitating effective professional development to promote the integration is difficult for organizational leaders to consistently achieve. Reimer, Farmer, Klein-Gardner (2015) reported that supporting the duration to achieve effective professional develop is a challenge to leadership. Planners of professional development, especially those in leadership, must consider evidence based findings to determine the scope and sequence of learning opportunities for practitioners in the classroom. Developing content and pedagogical content knowledge drives planning, which can be buoyed with specific attention to reflection within the learning experience.

Reflection

The use of reflection to facilitate teacher learning is well established. Reflective characteristics of learning described by Schön (1987) provide the theoretical frameworks in many studies showing that hands on engagement along with reflection on learning supported teacher learning (Payr, 2014; Schneider & Plasman, 2011; Crismond &

Adams, 2012). Payr (2014) confirmed results reported by Banages (2013) related to reflection and hands on interaction providing meaningful development of the content and enhanced teacher learning. Schneider and Plasman (2011) highlighted in their review of science teacher learning progressions that reflection emerged as a critical component of teacher growth, and manifested in ways that were associated with the teaching experience.

Bybee (2015a) highlighted the role of reflection as a critical component in the development of scientific literacy when used within the strategy of scaffolding. Scaffolding demonstrated the potential to promote core discipline ideas as well as facilitating the application of cross cutting concepts. Metacognition and reflection emerged as key factors in the process of scaffolding learning. The development of engineering fluency is also facilitated with reflection. As suggested by Cunningham and Carlsen (2014), reflection is a component of meaningful professional development after manipulating materials and then reflecting on the activities with other participants and the instructors. During the implementation phase, reflection supports the development of engineering fluency by trying new components of the process, reflecting on the outcomes and then moving onto new focal points (Cunningham & Carlsen, 2014).

Custer and Daugherty (2009) align with research that advocates for effective professional development which utilizes reflection to promote deeper understanding of the content. Of interest is the explicit mention of the use of reflection to facilitate learning of participants within the role of teacher as well as their own learning as a student. Research which focused on teacher development to transition to a STEM school noted the importance of reflection to the development of teaching (Teo & Ke, 2014). Teo and Ke (2014) recognized that uncertainty regarding aspects of the teaching profession including selection of curricular materials, assessments and instructional planning, were effectively addressed with reflection as a component of learning about practice. This focus on the improvement of practice within practice mirrors Schön's theory of learning in action (1983). Reimers et al., (2015) called for a similar emphasis on reflection within courses to deepen participant understanding.

In contrast to these reports, de Vries (2013) described that reflection was not reported by teachers as an effective learning mechanism as compared to coursework or peer collaboration. It is noteworthy that de Vries (2013) speculated that reflection was a more difficult vehicle to recognize as facilitating learning as compared to the other treatments within the study. The participants' years of experience averaged 18.8 years and yet reflection was not identified as a primary learning mechanism, suggesting that maybe reflection was uncomfortable for participants to engage in or possibly recognize. This may suggest an under-representation within the findings. Reflection of how one's practice has changed over time, a reflective approach to improvement, was established to be an important variable in teacher learning in recent studies (Bakkenes, 2013; de Vries, 2013). The influence of contextual factors such as students, administrators and colleagues emerged as key factors within reflection approaches to teacher development, particularly in the case of developing a grasp of the nature of science (Akerson, Pongsanon, Weiland, & Nargund-Joshi, 2014). Of interest, though not well understood, is teachers' self-awareness of reflection as a mechanism to develop understanding and support personal growth in not only content knowledge but in the art of instruction.

Pedagogical Content Knowledge

In response to reforms found within the NGSS educational leaders at all levels are asking elementary teachers to provide instruction on concepts in which the teachers themselves have little experience or understanding of. This lack of background is related with the risk of classroom instruction filled with missed opportunities to support student growth along the learning progressions for each of the STEM disciplines. Pedagogical Content Knowledge (PCK) as described by Shulman (1987) describes the understanding of approaches and nuances of teaching particular topics.

Developing PCK is specific to topics and is seen in the translation of effective instructional approaches which are suited to particular subjects (Crismond & Adams, 2012; Van Driel & Berry, 2012). Crismond and Adams (2012) determined that teachers with high pedagogical content knowledge understood the learning progressions and trajectories for topics, including the concepts, misconceptions and assumptions that students most likely will enter the classroom with. This knowledge influenced lesson planning and the establishment of effective timelines of instruction by participating teachers, leading to effective instructional practice (Crismond & Adams, 2012).

Bissaker (2014) noted that instructors require knowledge and strategies to design and support appropriate learning opportunities for students that promote both meaningful engagement with the content as well as moving through the process of inquiry-based learning. Existing methods and approaches to instruction are no longer sufficient when significant change comes through reform such as the NGSS. Perkins and Reese (2014) cautioned leaders that these changes must be anticipated and acknowledged to best support teachers through the adjustment. Additional support to develop pedagogical content knowledge for pre-service and in-service teachers is needed at all grade levels. The use of the engineering design process as a strategy for increasing student learning is questioned in the work of Chen, Moore and Wang (2014). Chen et al (2014) focused on pedagogical issues mentioned within the framework for K-12 science education that shape how the NGSS are interpreted. Chen et al. (2014) advocated for reflective learning through the application of prior and new knowledge in a context that has a real world setting to develop both content understanding as well as pedagogical content knowledge.

Teacher learning through interaction with higher education faculty promoted thinking and dialogue centered on new content and pedagogy (Bissaker, 2014). Handa (2013) identified areas which promoted individual and group pedagogical content knowledge. These areas included social, affective and cognitive domains that supported teacher learning. Choi (2011) identified similar conditions when examining change agents at the organizational level. Fullan acknowledged that leadership plays a strategic role in advancing systemic change and these factors must be considered within the context of promoting teacher change (2008).

Deeper PCK may also support teacher recognition of connections among subjects. As noted in the 2015 report, the NRC recommended that for implementing the NGSS, elementary teachers will need support to develop understanding of relationships between science, mathematics, and language arts. This will be critical for elementary teachers who are responsible for teaching multiple subjects throughout the day, and who currently spend little time on science instruction (NRC, 2015).

The notion of what PCK needs are for teachers at various stages of their teaching career is an emerging field (Schneider & Plasman, 2011). Pedagogical content knowledge can provide a lens to view the understanding of science content knowledge for teachers at various stages of their career. Consideration of pedagogical content knowledge can inform the development of science learning for teachers throughout their careers.

Science

Traditional science instruction by teachers viewed science as both a body of knowledge and a compilation of procedures to be passively transmitted from teacher to student (Grigg, Kelly, Gamoran, & Borman, 2013). Proficiency had been identified with factual assessments and confirmation laboratory experiences. The failure of this approach to develop scientific literacy within students drives a need to shift instructional design to emphasize modeling and advance scientific inquiry (Griggs et al., 2013; Roehrig, Michlin, Schmitt, MacNabb & Dubinsky, 2012). Achieving college and career ready students necessitates emphasis of depth and breadth for both content and practice which are emphasized in the NGSS (NGSS Lead States, 2013). Preparing teachers to introduce the applications within the NGSS necessitates not only an increase in use of science inquiry approaches, but also incorporates specific content and pedagogical content knowledge strategies. The breadth and depth of science knowledge that teachers should be familiar with is expansive. Depending on the grade level of instruction teachers are tasked with understanding the foundations within the fields of biology, chemistry, physics, earth and space science, all of which depend on a foundation of mathematics (NRC, 2010). Elementary teachers have science curriculum which introduces students to each of the science domains.

While student achievement is influenced by prior experiences, Kanter and Konstantopoulos (2010) found that achievement in science had a correlation to teacher content and pedagogical content knowledge. Student achievement in science is also strongly correlated to the time spent doing science at the elementary level (NRC, 2015). Experiences similar to those of an inquiry approach exemplify the meaningful experiences described by Schön (1983) as promoting learning. Supporting student achievement therefore is influenced by teacher preparedness and is an area of professional development that should continually evolve.

Few elementary teachers indicate that they are ready to teach science. As noted by Sandholltz and Ringstoff (2014) elementary teachers report feeling unprepared to teach science as compared to mathematics or language arts. The standard teacher preparation program involves two laboratory science courses (NRC, 2010). Elementary teachers have been called on to increase their instruction of both science and engineering and capitalize on the natural curiosity of students (Lachapelle & Cunningham, 2014). The interest to design, build, and explore that children enter the class with, can serve as a leverage point for teachers to introduce the science and engineering practices at the elementary level. This prospect exists if teachers recognize and make the most of these opportunities (Bybee, 2011).

Engineering

Roehrig, Moore, Wang and Park (2012) examined the impacts of mandated reforms which included the integration of engineering into secondary science curriculums. Their research used a framework of content integration and context integration to examine understanding through implementation. This dual approach captured the learning process for the secondary teachers at multiple angles. Engineering design was integrated into curriculum through collaborative planning and was identified as an effective entry point for teacher engagement and integration of concepts from STEM (Roehrig et al. 2012). Engineering design promotes the use of the design cycle to solve problems or improve solutions to meet human needs. The use of science and mathematical principles to inform design choices leads to movement through an iterative cycle which optimizes design solutions. The professional development approach of Roehrig et al (2012) could transfer to another teacher group such as elementary teachers. Daugherty and Custer's review of studies examining the use of engineering design in professional development focused on teacher learning of engineering concepts and the reflection of the concepts within instructional planning (2012).

A lack of math and science background emerged as a factor impeding the integration of engineering design at various grade levels (Daugherty & Custer, 2012). Roehrig et al., (2012) also found various levels of engineering implementation that could be correlated to teacher backgrounds, supporting Daugherty et al.'s conclusion that prior understanding and expertise influences the outcomes of learning new content. These conclusions are in contrast with previous policy approaches to focus time and resources on fundamental skill building within the areas of literacy and mathematics within the lower primary grades (Fisher, 2015). Current policy makers have recognized the need to shift to a STEM focus and have begun to advocate for science, mathematics and technology along with engineering to align with career and workplace readiness beginning in early elementary school (National Governors Association, 2011). Reimers, Farmer and Klein-Gardner further strengthen the call for increased support to learn engineering concepts. The authors (2015) described the current background knowledge of K-12 classroom teachers as both lacking formal training in engineering as well as in experience which limits the integration of engineering into classroom practice.

Mentzer (2011) previously utilized a contrasting framework which centered on the iterative nature of the design process as a mechanism to measure concept understanding. Findings based on secondary student use of the engineering design process showed progressions towards independent application of the concept with experience. Mentzer (2011) as well as Roehrig, Moore, Wang and Park (2012) found evidence of increased science content understanding with the infusion of engineering design within the science curriculum. The self-selective nature of participants in the secondary level classes within the programs however introduces the possibility of limiting the generalizability of the findings. Lehman, Kim and Harris (2014) scrutinized how designed based learning could be extended within a collaborative learning model. Gains for participating groups, elementary classroom teachers and higher education faculty, were attributed to the collaborative interaction and reliance on group expertise. Lehman et al (2014) confirmed the need that elementary teachers require professional development support in the selection and implementation of the engineering related concepts being integrated into science curriculum.

Roehrig et al.'s (2012) findings are applicable to the formal class setting and are focused through the lens of lesson design. The work of Redmond, Thomas, High, Jordan and Dockers (2011) examined informal programs, and did not find significant changes in science or mathematics conceptual understanding through participation in programs with engineering integrated in. They did determine there was an increase in interest in STEM after participation; an important factor to maintain motivation in learning. Informal setting research confirms an increased interest in STEM following an introduction to engineering concepts (Sahin, 2013).

Of note is the issue of few reliable instruments to measure the learning of in-service teachers within STEM topics (Saxton et al., 2013). The grounded theory work of many research teams attempted to unify conceptual frameworks based on constructivist, change and uncertainty theory which currently examine teacher learning issues (Capobianco, 2011; Redmond et al., 2011; Saxton et al., 2013).

Work by Liu, Carr and Strobel (2012) identified engineering related concepts that support developing an understanding of the engineering field. These concepts are presented to teachers in various professional development formats, including online. Liu et al. (2012) noted that the foundational concepts to develop around engineering include

- Knowledge and appreciation of engineering,
- Identification of different disciplines within the engineering field,
- Application of the engineering design process,

- Connection to disciplines including math, science and language arts, and
- Awareness of resources that could support the classroom.

Liu et al.'s (2012) conclusions related to strategies which promote deep learning vary from the seminal work of Custer and Daugherty (2009) who promote that engineering concepts are better understood through experiences such as collaboration, teamwork, documentation and communication. These outcomes were confirmed by Reimer, Farmer and Klein-Gardner (2015) and strengthen the position that Custer and Daugherty hold within the field.

Strohlmann, Moore, and Roehrig (2012) described strategies that support student learning, and which are applicable to teacher learning of new content also. These

- Build on prior knowledge,
- Organize knowledge through development of big ideas and themes,
- Highlight in an explicit manner the interrelationships of both concepts and processes,
- Promote deeper understanding through discourse, and
- Construct knowledge through time.

Cunningham and Carlsen (2014) cautioned that the prominence of engineering within the NGSS provides a framework to think about the practices, disciplinary core ideas, and the cross-cutting concept but that the language implies that engineering is the application of science solely. Therefore, appreciation and understanding of engineering concepts on their own, and awareness of the distinctive characteristics of the engineering process and associated fields could be limited without substantial professional development. The authors argued that the engineering process is distorted within the NGSS, particularly with respect to the practices of science and engineering and that an unrealistic view of engineering could develop. A substantial amount of research by Cunningham and Carlsen (2014) advocates for the following components to promote accurate teacher understanding of engineering to

- Engross teachers in the practices of engineering from the NGSS,
- Model pedagogical strategies which support the practices,
- Provide experiences to participants as both teachers and learners,
- Be explicit with interconnections that exist between science and engineering for teacher understanding, and
- Highlight the social practice of engineering with teachers.

Approaches to increase engineering understanding are not exclusive to other disciplines. Research which examines engineering as an integrated component of the disciplines of STEM examines and builds on each discipline alone and sheds light on unique features of the areas considered together as STEM. Individuals who focus instruction through a STEM lens are also making adjustments in response to the NGSS and these changes are found in all grade bands.

STEM Integration

STEM integration is challenging at any level, and has specific barriers at the elementary grades. As noted by the National Academies of Science, Engineering, and Medicine (2015), 39 percent of elementary classes did not have science instruction weekly. Of those teachers who did include science within their weekly instruction the time was limited to 20 minutes daily (NAP, 2015). The reduction in time of science instruction may be correlated to the increased expectation to focus on mathematics and language arts (Nadelson et al., 2013). An alternative explanation that Nadelson et al. (2013) put forth was the confounding variable of inadequate teacher preparation.

Few practitioners at the elementary level report they are adequately prepared to teach science or engineering, key facets of STEM education (Guzey, Tank, Wang, Roehrig & Moore, 2014). All elementary teachers are expected to teach STEM now as articulated through NGSS. Traditional certification programs for elementary teachers often mandate only two science laboratory courses and two mathematics courses as requirements of the certification process (National Research Council, 2010). Effective professional development can increase content knowledge of K-12 teachers as Reimes, Farmer, and Klein-Gardner (2015) observed that K-12 teachers with no engineering experience have an increased need for professional development experiences as compared to mathematics and science support. Additional professional development could support teachers with the integration of STEM.

The term STEM lacks clarity amongst the education community. STEM education has been defined as

> A standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study" (Merril & Daugherty, 2009). Further concerns regarding the implementation of

> STEM center on the need for authentic contexts and the treatment of the traditional classes in relation to how STEM will look when implemented. (Brown, R., Brown, J., Reardon, & Merril, 2011, p. 6)

Implementing STEM within the classroom with an integrated approach has varied in format and effectiveness. As Guzey et al. (2014) noted widespread diffusion of innovative classroom practices to promote systemic change has not occurred with previous reform efforts. Professional development support however did emerge from previous efforts as a critical variable to increase the likelihood of enhanced student achievement. Design of professional development that supports teacher growth has varied in regard to models of duration, facilitation and focus. Outcomes have ranged in regard to effect and lessons learned which can inform improving professional development experiences for in-service elementary classroom teachers who are tasked with enhancing the content and pedagogical content knowledge related to STEM concepts that are promoted by the NGSS.

Elements of Professional Development

Research has focused on the impact of professional development in the support of teacher learning (Guzey et al, 2014; Reimer, Farmer, Klein-Gardner, 2015). Identified elements such as co-teaching, collaboration and self-reflection supported adult learning in various contexts including professional learning communities which may translate to teacher learning of science and engineering concepts. Supplementary research also found that successful professional development led to increased content knowledge (Guskey, 2003; Reimer, Farmer, Klein-Gardner, 2015). Outcomes from Reimer et al (2015) demonstrated that effective professional development led to changes in teacher behavior reflecting an ability to evaluate curriculum resources. This is a critical skill needed by teachers who will evaluate NGSS aligned resources as they roll out in the future.

Bissaker (2014) examined professional development approaches pairing higher education academics with classroom teachers. The strategic partnerships facilitated an ability to generate innovative curriculum in addition to increased content knowledge growth for the participating teachers. An unexpected increase in pedagogical strategies for both the classroom teachers and faculty participants was also observed (Bissaker, 2014). Sensemaking of the content and approaches in a manner that reflects Schön's (1987) learning theory and Weick's (1995) group learning work also mirrored changes in teachers' beliefs and attitudes within the program (Bissaker, 2014).

A similar examination of the impact of collaboration between teachers framed the integration of the Next Generations Science Standards into the school curriculum. Allen and Penuel (2014) found effective professional development experiences included those which incorporated active, hands-on learning. Sensemaking approaches utilized by the teachers to reconcile professional development and district goals increased teacher fidelity for those teachers who worked to incorporate the NGSS into their existing curriculum.

The National Academies of Science, Engineering and Medicine (2015) cautioned that ongoing support, recommended as a professional learning community will be needed even after the "transition phase" to the NGSS. Continued efforts to understand and improve teacher and leader understanding of the NGSS will be needed across all levels of teacher or student background (NAP, 2015). Recommendations from NGSS leadership to supervisors related to transition timelines call for a five year period to provide support for the translation of the standards to practice within the classroom (NAP, 2015).

Developers of other reform mandates, most notably the Common Core, have called for similar timelines to support proper implementation (Bakeman, 2013; California Department of Education, 2013). Many leaders have varied the assessment expectation timelines for the Common Core. Advocates in states such as New York have called for the suspension of the assessment piece, and more resources directed towards professional and curriculum development (Bakeman, 2013).

Previous reform mandates have utilized similar implementation approaches with mixed success. The No Child Left Behind (NCLB) act of 2001 was crafted to ensure that all children would be proficient in mathematics and reading by 2013-2014 (Vernez, Birman, Garet & O'Day, 2010). The additional measure of accountability increased the complexity of measuring adequate yearly progress (AYP) and as Vernez et al. (2010) reported the variation in school improvement practices has made reaching the reform mandates difficult. Implementation over the initial five year period demonstrated growth in many schools and revealed systemic issues that create challenges for reform to be sustainable. Variability in meeting AYP accountability measures also contributes to difficulty in evaluating NCLB impact. Vernez et al. (2010) determined that many subgroups such as Hispanic, African-American and white did show growth in AYP when population size was large enough to evaluate based on ethnicity. Other groups such as

Native American’s often did not meet the sample size requirement to evaluate AYP for these groups.

NCLB efforts build off the foundation created during the Elementary and Secondary Education Act reform movement of 1965 (US DOE, 2016). Outcomes such as Title 1 funding strive to support student achievement in a more equitable fashion. The distribution of resources contains several facets, including supporting teacher professional development. The Elementary and Secondary Education Act has been reauthorized under the current Every Student Succeeds Act (US DOE, 2016). Differences in how to best move change forward have kept reauthorization at bay for over seven years (National Schools Board Association, 2015). Addressing unintended consequences of NCLB as well as promote 21st century skills for all students remained the focus of the reauthorization updates (NSBA, 2015). Throughout all discussions, a top priority continues to be the focus on the support and development of teacher knowledge and pedagogy to effectively implement standards at the applicable level.

Developing teacher understanding of appropriate engineering concepts is aligned with the grade level of instruction in the classroom (Lachapelle & Cunningham, 2014). At the elementary level, special attention is needed to target the developmental concepts and skills for students. Professional development and support for curricular selection of materials and resources is needed for teachers of elementary students to ensure that engineering understanding is developed in a manner that a foundation for more complex work in higher grades.

Consideration of teacher experience is another variable in the planning of meaningful professional development. Schneider and Plasman (2011) investigated the unique question of pedagogical content knowledge development of teachers at varied stages of their career. Pedagogical content knowledge understanding was not directly correlated with teaching experience but in fact was linked to prior professional development activities that were related. Therefore, effective professional development should build upon past experiences to maximize teacher learning not only of content knowledge but to enhance pedagogical content knowledge, and this is lacking with STEM professional development (Schneider & Plasman, 2011). Consequently, teacher pedagogical content knowledge growth may be supported with appropriate planning and duration of teacher learning experiences.

Summary and Conclusions

Calls for reform to science education have come from local, state, and national levels. As the economy continues to grow there is an increasing dependency upon a foundational knowledge of science, mathematics, technology and engineering (Allen & Penuel, 2014; Lehman, Kim, & Harris, 2014; Schneider & Plasman, 2011). This chapter provided an overview of the current understanding within the field that relates to teacher learning of science and engineering education. Promoting an understanding of STEM disciplines with the overarching goal of furthering student achievement is a target within many programs (Marion, 2014; Fullan, 2012; Poekert, 2012). The state of teacher readiness to meet this task is questionable. This is a concern at the elementary level, where teacher ability and confidence to teach science or engineering is low. Shifts represented in the NGSS (NGSS Lead States, 2013) will require elementary teachers to use practices aligned with scientists and engineers, a new demand on elementary teachers. The framework of reflective learning (Schön, 1983) provides insight into how adults address challenges of continuous learning in the workplace. Work by DuFour and Fullan (2013) identified conditions to promote learning and they exemplify reflective approaches. Weick (1995) examined reflective learning as sensemaking within the context of organizational change. Reflective learning provides a lens to view the changing needs of K to 6 teachers as they respond to the NGSS.

Description of prior research presented in the literature review focused on changes in content knowledge and pedagogical content understanding of teachers, particularly those at the secondary level. A review of evidenced based programs revealed that supporting secondary teachers was well researched but uncovering the mechanism by which this support translates into changes in classroom practice, or how these changes occur at the elementary level, is poorly understood (Daugherty & Custer, 2012; Stohlman, Moore, & Roehrig, 2012; Patricia, Nanny, Refai, Ling, & Slater, 2010). Consequently, to support the effective transition to the NGSS there is a need for a deeper understanding of elementary teachers' perceptions of learning needs as related to both science and engineering content and pedagogical content knowledge. This qualitative interview study identified and described the perceptions of the learning needs of elementary in-service teachers and their administrators who facilitate learning within the school. A deeper understanding of these learning needs can inform professional development planning as teachers' transition to the NGSS.

A focus on the specific characteristics and needs of elementary teachers addressed challenges and barriers of ongoing learning for the classroom. Challenges and barriers at the organizational level were also examined. The following chapter provides an overview of the research design and rationale used to investigate these perceptions related to elementary teacher learning and the perceptions of administrators of teacher needs for continuous learning in transitioning to the NGSS.

Chapter 3: Research Method

In the literature review, I revealed a lack of understanding surrounding how elementary school teachers approach the learning of new constructs such as novel science and engineering content in the classroom. Responding to education reform policies such as the NGSS often prompts the need for practicing teachers to expand both their content and pedagogical content knowledge (Schön, 1987; Weick, 1995). This new learning underpins changes in classroom practice with the goal of increasing student achievement. The purpose of this qualitative interview study was to explore in-service elementary teachers' and administrators' perceptions of what constitutes supports and barriers to facilitate their own learning of novel science and engineering concepts and pedagogical learning in a mid-Atlantic urban school setting of the United States. The unit of analysis was with teachers and building administrators.

This chapter is organized to present information related to the research method for the study. The research design and rationale are described, and the role of the researcher is clarified. Explanations of the methodology and instrumentation are provided along with specific attention given to the approaches to participant selection and recruitment, data collection, and data analysis strategies that were applied to the data collected. Validity and ethical issues were also considered.

Research Design and Rationale

Since this study was an examination of elementary teacher perceptions of ongoing learning of science and engineering and I sought to identify what supports and facilitates their learning as well as challenges and barriers to their continuous learning, a basic qualitative study interviewing teachers and administrators was used. The following research questions were addressed:

Research Question 1. How do elementary teachers perceive their needs for learning new science and engineering content knowledge and acquiring pedagogical content knowledge for teaching in response to NGSS reforms?

> Subquestion 1. What strategies do elementary teachers perceive would provide support for learning new content and developing pedagogical content knowledge?
>
> Subquestion 2. What do elementary teachers perceive are the barriers and challenges to learning new content and pedagogical content knowledge regarding NGSS?

Research Question 2. What do administrators believe are the barriers and challenges to the implementation of mandated NGSS?

The central focus of this study was the set of perceptions and experiences related to learning of science and engineering by elementary school teachers and administrators as they attempt to work with NGSS. The theoretical foundations of Schön's (1983) framework of reflective learning proposes that unsettling events, such as what teachers face in adapting to NGSS reform efforts in education, often create an awareness for the learner that there is a gap in understanding and that this awareness creates motivation for new learning. Weick (1995) built upon this foundation with the use of learning within the context of the term sensemaking. Weick's idea of sensemaking describes the process that groups such as teachers go through when tackling new learning and how this new information is put within the context of past understanding and prior experience.

The research design for this inquiry was an interview study. An interview study investigates some phenomenon of interest within a natural setting and allows the researcher to capture information about experiences that cannot directly be observed (Patton, 2002). Capturing the reactions, motivations, and approaches to learning, such as for in-service teachers through their responses in an interview setting, aligns with an interview study design (Patton, 2002). An interview approach can pursue in-depth information that is related to the topic of interest with semistructured questions and follow-up probes (Valenzuela & Shrivastava, 2008).

My rationale for choosing this basic qualitative design using interviews was to allow teacher and administrator experiences to emerge as a voice in an inductive manner. The interview approach capitalized on flexible aspects of a semistructured protocol that allowed for clarifying and follow up questions. A deeper understanding of the experiences will support a meaningful grasp of the challenges and opportunities within teacher learning. Alternative qualitative approaches were not as well aligned to explore the research questions. A narrative study would mainly highlight the description of the phenomenon while a case study approach would focus on the generalizable aspects of the unit of study. Quantitative approaches, which tend to have a deductive approach and focus on testing theory, were not appropriate as research design approaches to answer the research questions in this study at an in-depth, detailed level.

Role of the Researcher

As with most qualitative research, as the researcher I served as the primary instrument for data collection. My role as an observer aligned with the features of an interviewer. The 13 participants in this study were employees within an urban district in which I had provided professional development support to middle school and high school teachers, but not K to 6 teachers. I had interacted with select middle and high school teachers who participated in a National Science Foundation Discovery Research K12 grant program and a state partnership program that was administered through a local university where I am employed. A component of the programs included workshop development and coaching that I provided to participating teachers to support their development of science concept understanding. I did not, however, have any supervisory or evaluative interactions with any of the teachers in the district and am not an employee of the district.

The potential for researcher bias exists within any qualitative research based on previous life experiences and prior understandings (Patton, 2002). My experiences as a former classroom teacher and professional development provider created a background of understanding. I have taught in multiple settings, including urban and suburban districts and at levels ranging from middle school science to undergraduate level science. I have not formally worked as an elementary school teacher but have been involved in providing support to teachers at the elementary level through other work experiences. While this experience and background could possibly influence how I interpreted the data I collected, I kept a researcher’s log to document my own reflections to watch for bias during both the data collection and analysis phase. Taking care to minimize this potential bias was also addressed in the research design with interview questions developed within a conceptual framework and interview protocols created for consistency in data collection. A possible ethical issue was that an incentive was provided to participants. The data collection through interviews occurred outside of contractual obligations within their district, and the participants were compensated for sharing their professional expertise. The value of compensation reflected what the district pays for professional development time, and participants received a $25 gift card. The data analysis plan described below was also established from theory to minimize bias and strengthen conclusions. In the next section, I provide further details on the methodology that was used in the study.

Methodology

Within this section, I describe the participants, sampling method, and instrumentation used in the study. The participant discussion includes characteristics of the teachers who were recruited for the study. The sampling method was defined with specific attention to sampling size explained. The instrumentation that was used within the study is also explained and is related to the overall goals of the research project.

Participant Selection

There were two groups of participants for this study: K to 6 teachers and administrators. Both sets of potential participants were employed in a suburban district with 11 elementary schools with diverse ranges related to both the ethnic and the socioeconomic characteristics of the student body. The superintendent of the schools in the district provided me permission to conduct the study with access to those K to 6 teachers and administrators in the district. K to 6 elementary teachers were recruited through an invitation to participate within the research study. These invitations were emailed to the K to 6 teachers from building faculty lists on the school web sites. In this way, intensive, purposeful sampling as outlined by Patton (2002) was applied to the recruitment of teachers with the expectation of having eight to 10 participants from this group.

Administrators constituted the second group of participants for the study. They were interviewed with the purpose of providing a perspective on the professional learning opportunities and expectations within their building and district. Administrators included individuals such as principals who manage school operations and coordinate curricula, oversee teachers and other school staff, and facilitate the learning environment for students (Abbott, 2014). The administrator personnel also were identified from district web site information, and an initial target population of five to seven administrators was used. These administrators were emailed and invited to participate in the study. This reflected purposeful sampling of both teachers and administrators within the study.

Purposeful sampling strengthens qualitative research designs based on the selection of information rich cases (Patton, 2002). If there is an alignment between the interview protocol and the research questions, there is an increased likelihood of gaining deeper understanding and insight into the phenomenon being investigated. As recommended by Patton (2002), the use of specific purposeful strategies during the sampling phase can lead to the presence of suitable cases from which the investigator would potentially learn the most. Studies of teacher learning in recent years informed the research design of this study, and a sample size of 10 to 12 participants was identified as the optimal target recruitment number (Capobianco, 2011; Nilsson, 2014). Because the sample for this study came from one school district, proportionally, the sample size of eight to10 teachers potentially represented a range of teacher experiences and backgrounds as well as professional learning experiences. The target population also had science as part of their teaching assignment, and they were employed as full time elementary teachers.

Patton's (2002) intensity sampling strategy was chosen for this study because it maximized the inclusion of appropriate individuals for interview study research. This sampling approach provided access to information rich participants who represented strong examples of the phenomenon of interest without a focus on extreme occurrences. Intensity sampling, therefore, was the desired means to access information related to the phenomenon within the topic of focus. The defining characteristic in this study were in-service elementary teachers who had science within their teaching requirement.

A key variable within the research design that is informed by intensive, purposeful sampling strategies, according to Patton (2002), is the sample size. Redundancy of data gathered within the collections is desired, but achieving this ideal was limited by time and resources for this study. These constraining factors may limit the level of redundancy within a sample (Patton, 2002). This sampling plan still permitted enough data to be collected and I was able to proceed with investigating the research questions that were part of the study. Minimum sampling required checking for representativeness as part of the selection of participants (Miles, Huberman, & Saldana, 2014). Recruitment ended when the target participants of eight teachers participants and five administrators was reached.

Instrumentation

The use of interviews was an effective approach to collect information to better understand participant experiences and the phenomenon under investigation (Maxwell, 2013). Semistructured interviews served as the primary data collection approach for this research study. According to Patton (2002), the depth and richness of responses can be facilitated with the use of probes and follow-up questions within a semistructured approach to interviewing. One-on-one interviewing provides optimal conditions, including access to identified target populations and increased engagement by the recruited teachers because of the flexibility allowed for time and location with one-on-one approaches. Subjective understanding of the participants' experiences, suggested by Seidman (2013), was the approach taken in this study.

As noted by Miles et al. (2014), the skills of the researcher relate to the reliability and validity of information collected throughout a study. Effectiveness should be prioritized in regard to the actions of the researcher-as-instrument. One step in this process was the development of interview questions that engaged the participants in a manner that facilitated their reflection of prior learning experiences (Seidman, 2013; Yin, 2014) and allowed me to explore their perceptions.

The interview questions for both teachers and administrators (Appendix) were developed and refined by me during the Walden Advanced Qualitative Research course and in consultation with my committee. Question development stemmed from the literature review and my experience in professional development. Refinements to the questions focused on strengthening content validity through the feedback of the instructor and other educators in the class. Building on the concepts of Schön's (1983) reflective learning and Weick's (1995) construct of sensemaking, the questions and flexibility within the follow-up queries were designed to support the exploration of teacher learning perceptions and how science and engineering concepts are approached. The interview protocol was designed to align with Seidman's (2013) approach to maximize subjective understanding. With the aim of providing sufficient data during collection, the questions were developed and mapped to the research questions to ensure the scope and sequence of the research remains focused on describing the phenomenon identified in the research plan. The interview questions were designed to prompt responses to each of the research questions and to encourage participants to reflect on their approaches to learning. The questions were open-ended to afford participants the ability to contribute additional information that is not directly asked. The techniques advocated by Seidman guided the format of the interviews, with attention being given to listening more, talking less, and looking for the "inner voice" of each participant.

Procedures for Recruitment, Participation, and Data Collection

The procedures for recruitment, participation, and data collection are conveyed in this section. In this interview study, I used 45 to 60-minute face-to-face interviews for teachers and a 40 to 60-minute face-to-face interview for administrators using interview protocols with questions mapped to the research questions for the study. Aligning the procedures through the use of protocols created a systematic process to these components of the study (Maxwell, 2013). Following a systematic method during recruitment, participant selection, and participation, as well as the data collection and analysis, increased the trustworthiness of the study. I describe the recruitment approaches that were used are described in the following section.

Recruitment

The K to 6 teachers were sent an email invitation to participate in the study; the email described the criteria of their grade level and science teaching assignment needed to become a participant for the study. The email invitation included the study goals, requirements, and commitments needed from the participants. Teachers who responded to the email were asked to confirm that their teaching assignment was K to 6 and included science. The target number of teacher participants was eight, based on the research design plan that was informed by previous research in the literature. Administrators were similarly recruited through an email invitation. The target number of administrator participants was five. Potential participant contact information was located on the district web site. Faculty names, emails, and grade assignment were accessed through the home web page of each school.

Participation

Once teachers and administrators responded and I determined that they met the desired criteria, I sent them an informed consent to participate in the study. The informed consent was explicit in regard to participant obligations and timelines and also provided information on benefits, risks, and withdrawing from the study. These individuals were then contacted by email to set up a face-to-face interview time. Interview time slots were 1 hour each and were recorded using two digital recorders. The files were downloaded to a USB flash drive and stored on my private, password protected computer. Once I transcribed the interviews, teachers and administrators were provided with a copy of the interview transcript as a method of member checking. After their feedback was noted, their participation in the research study concluded. Participants each received an honorarium of a $25 gift card each for their participation in the study. Teachers and administrators had the ability to withdraw at any time prior to completion of the interviews.

Data Collection

Interviews were conducted face-to-face, one-on-one in a comfortable private setting that was chosen by the participant. The 8 teachers chose to be interviewed off campus, at local coffee shops that provided privacy. The administrators elected to be interviewed at their school site, in conference rooms that provided privacy. The interviews began with introductions and establishing a rapport with the participant. Interview time slots are anticipated to be one hour, and were recorded using two digital recorders and the file downloaded to a USB flash drive. I transcribed each interview and saved the files on my password protected personal computer.

I emailed each participant a copy of the interview transcript for their review as a method of member checking. The teachers returned the transcripts via email and raised any concerns with comments to accurately reflect their perceptions and experiences related to the study. Seven teachers returned the transcripts without any revision and one completed the member checking protocol with slight revisions that altered word choice in one response section. Administrative feedback followed a similar process. Transcribed copies were emailed to the administrators and one administrator provided addition examples to illustrate examples related to one of the interview questions. Once the transcripts were returned and their feedback noted, teacher and administrator participation in the research study concluded. Participants were compensated for their contribution to the study with a $25 gift card. Teachers or administrators retained the option to withdraw at any time prior to this point.

Each interview was recorded using two recording devises to ensure completeness of data collection and accuracy during the transcription process. I also kept field notes to reflect any observations I had during the interviews as another data source related to my own biases. All data was stored on my personal password protected computer and locked file cabinet for five years and only pseudonyms were used in reporting results to ensure confidentiality.

Data Analysis Plan

As described earlier, the data collected through the interviews was aligned to specific research questions. Schön's (1987) theory of reflective learning, and Weick's (1995) work with sensemaking, informed the development of provisional codes that were applied during data analysis. I generated these starter codes to replicate attributes of reflective learning such as hands-on experience or active participant. InVivo coding also was applied to capture and honor the participant voices and highlight participant language which repeats and lead to identifying patterns within the data (Miles et al., 2014).

The analysis process that I applied included provisional coding to the start of the evaluation and open coding in later stages. This two stage approach promoted the thorough identification of categories and themes. Software analysis confirmed the categories and themes identified by the researcher. Peer debriefing was also utilized to engage in discussions with a colleague and process the emerging themes. Theoretical propositions as described by Yin (2014) framed the analysis strategy and guided the exploration of the phenomena. These plans became the framework for the analysis and reflect the work of Schön (1987) and Weick (1995). The analysis embodied the factors contributing to adult learning as put forth by Schön (1983, 1987) and Weick (1995) and revealed through analysis of the interview data. These influences emerged from the contextual descriptions provided by participating teachers and administrators when identifying how they approach learning in new contexts, in this case the NGSS.

Provisional coding was applied during the first round of analysis. The factors which were identified from the literature as impacting teacher learning were applied as provisional codes (Miles et al., 2014). Factors such as hands on experiences within science, workshops, reflection and support such as coaching have emerged within the field as factors which support teacher learning (Daugherty & Custer, 2012; Ireland, Watters, Brownlee, & Lupton, 2012; Roehrig, Moore, Wang, & Park, 2012). These variables, as well as ones which emerged during further analysis, provided insight into the area of teacher perceptions of learning.

A technique of explanation building as a process was used in the analysis (Yin, 2014). I employed the schema related to adult learning that supported the research inquiry to make connections to the phenomena. Similarities to a spiral data analysis as described by Maxwell (2013) are evident. These similarities included the organization and processing of the data and the application of provisional and open coding. A resulting narrative emerged and software such as NVivo confirmed results through the use of features including word frequency and auto-coding.

Issues of Trustworthiness

The issues of trustworthiness within the study are addressed in the following section. Confidence in the results of the analysis was strengthened by the efforts to promote the constructs of credibility, transferability, dependability, and confirmability. Credibility issues were addressed by myself during the research planning and implementation of the study and were aided by the use of explicit protocols. Internal validation was promoted through thoughtful participant selection. I used a reflective journal to document my thinking throughout the study, and add to credibility. I used peer review of data to strengthen the credibility of the study through discussion with a professional colleague. I also enhanced credibility with the use of member checks with the participants so that I ensured that I have accurately captured their perspectives. Member checking also created the opportunity for participants to clarify their meaning.

Transferability was addressed primarily with the use of thick, descriptive interviews with the participants. Extending the relationships I have within the target school supported my recruitment and selection of appropriate teachers with varied backgrounds. Selection of teachers with diverse backgrounds and obtaining rich, thick descriptions of the teachers’ experiences contributed to transferability. Patton (2002) indicated that trust among the participants and the researcher contributes to the validation strategies within a study.

Dependability documents the natural setting and accounts for any variation seen. To enhance dependability, I used my reflexive journal to provide a lens to examine my influence throughout the study, which aided in a reflexive approach to the analysis of the data and the conclusions drawn. Validity was also addressed through the triangulation of interview data from teachers and building level leaders. An audit trail of the data that I created through data collection and analysis supported dependability and confirmability within the study.

To address additional issues associated with confirmability I was explicit with concerns linked with researcher bias. My background as a teacher and current work in the field of professional development influenced the viewpoint I worked from, and sharing this lens with the teacher participants as well as building leadership created a context for the study and the interviews that supported the study.

Ethical Considerations

I ensured that this research study complied with all ethical considerations and standards recommended by the Office of Sponsored Research at Walden University. Institutional Review Board approval was obtained prior to any recruitment or data collection for this research (# 06-24-16-0382364). I spoke with the Superintendent and provided an overview of the research goals and plan. A letter of collaboration was obtained from the district. Informed consent was obtained from the participants who were recruited through the protocol described earlier. Teachers or administrators retained the right to withdraw from the study at any time. No teachers who filled out consent forms and were interviewed withdrew from the study. To promote anonymity for the participants I removed all information associated with identifying any of the participants. Identifiers were removed from all data sources and these materials were secured and stored in a locked facility. This step enhanced confidentiality within the research study.

Summary

This chapter included a description of the research design and rationale for the study to explore K to6 teacher and administrators' perceptions of what constitutes supports and barriers to facilitate their own learning of novel science and engineering concepts and pedagogical learning. An interview study approach was applied for this qualitative study. The role of the researcher and methodology were discussed in the context of the research design. Attention was given to explaining the sampling approach and participant selection and how this method aligns with the research design and strengthens the study. The approach to recruitment, participation, and data collection was described and details associated with instrument development and the data analysis strategy were presented. I described considerations for ethical procedures that were put into place during the study and details to ensure trustworthiness were described. The next chapter includes an explanation of how this research design was applied to determine the results for this study.

Chapter 4: Results

The purpose of this qualitative interview study was to explore in-service elementary teachers' and administrators' perceptions of what represents the supports and barriers to deepening their own learning of novel science and engineering concepts. This included any associated adult learning needs they had. My intent was to gain a deeper understanding of the teachers' perspectives based on their personal experiences with professional learning and their responses to expectations arising from policy reform such as the shifts advocated within the NGSS. I also explored administrator perceptions of teacher learning needs in response to the implementation of the NGSS. I described their views as they related to the supports and barriers to teacher learning. The following research questions aligned with the study exploration and framed the development of the interview protocols informing the approach of the data analysis.

Research Question 1: How do elementary teachers perceive their needs for learning new science and engineering content knowledge and acquiring pedagogical content knowledge for teaching in response to NGSS reforms?

> Subquestion 1. What strategies do elementary teachers perceive would provide support for learning new content and developing pedagogical content knowledge?
>
> Subquestion 2. What do elementary teachers perceive are the barriers and challenges to learning new content and pedagogical content knowledge regarding NGSS?

Research Question 2: What do administrators believe are the barriers and challenges to the implementation of mandated NGSS?

This chapter is organized to present the results of the study. I developed the context of the study through descriptions of the setting and demographics. I also describe how the findings emerged through the analysis of data collected and the identification of constructs and themes related to the research questions. The analysis of the interview data is viewed through the lens of two related theories of adult learning, reflective learning and sensemaking. The steps I took to enhance trustworthiness within this qualitative study are clarified, and rich examples illustrate the findings.

Setting

This study took place in an urban school district in the mid-Atlantic region of the Northeastern section of the United States. In 2015-2016, the total student population of this district was 9,368. The school system included one high school and 11 elementary-middle schools. The school district provided for a diverse population. The State Department of Education classified districts based on socioeconomic risk factors, and this district was in the third lowest grouping, in which 64% of students received free or reduced lunches.

The interviews were conducted at a location of the participants' choosing to increase comfort and convenience. The interviews did not occur during instructional time, as the teacher interviews were conducted in July and August, and the administrator interviews occurred during noninstructional time in October. The locations ranged from local coffee shops and a diner to conference rooms in the school buildings. At each location, there was sufficient privacy to conduct the interview and maintain the requirements of the IRB. To provide additional context, districts in this state were expected to integrate all aspects of the NGSS by the 2017-2018 school year.

Demographics

The participants included eight K to 6 elementary teachers and five administrators. The teacher participants had an average of 14.5 years of teaching experience that ranged from 2 to 35 years. Each of the teachers was a regular education classroom teacher and had science as one of their curriculum requirements. The eight elementary teacher participants consisted of one male teacher and seven female teachers. Two of the teachers, assigned in the K to 3 level, taught all subject areas required by the state with a single homeroom of students, and six teachers were departmentalized, meaning that they taught only science, or taught science and mathematics or social studies to multiple sections of students in their grade.

The average number of years of experience within the current grade level that the participant teachers were assigned to was 5.5 years. Three of the participating teachers had 2 or less years of experience at their current grade level, while the other five teachers ranged from 4 to 10 years of experience. Experience at various grade levels in the K to 6 band was represented within the study. Participating teachers were assigned to the first, third, fourth, fifth, and sixth grades at the time of data collection.

The administrator participants included two males and three females. The administrators had a range of experience from 2 to 15 years. Four of the administrators did not have a degree in science or had never taught science during their teaching careers. The administrators had a range of teaching experience prior to becoming certified as an administrator. Two administrators had previous teaching experience as a special education teacher, one as a physical education teacher, and another as a physical education/web design teacher. The administrator who was serving as the science supervisor was an experienced biology teacher with 10 years of classroom experience at the high school level.

Two participants served as administrators in two different buildings within the district, while three were in their first position as an administrator. All of the participants within this study worked within the district as a teacher prior to becoming an administrator. Of note, none of the administrator participants had any experience outside of this district. One administrator, who worked as the science supervisor, did have 3 years of high school life science teaching experience prior to moving into administration. This participant also served as a guidance counselor at the high school for 2 years before becoming the district science supervisor. Table 1 lists the pseudonyms used for each participant and information about assignment and experience.

Table 1

Participant Demographics

Name	Employment assignment	Years of experience in current position	Total years of experience
Ann	Grade 4	2	2
Betty	Grade 5	10	35
Chris	Grade 4	2	5
Danielle	Grade 4	8	16
Fran	Grade 3	4	25
Gina	Grade 6	10	14
Helen	Grade 1	7	15
Jordan	Grade 4	2	2
Lynn	Principal	3	8
Max	Principal	3	3
Pat	Principal	2	3
Taylor	Science Director	3	3
Sam	Principal	4	7

Data Collection

Data collection began after securing a letter of cooperation from the superintendent of the district and obtaining IRB approval from Walden University (# 06-24-16-0382364). Email invitations were sent to elementary teachers within the district as well as the administrators. Faculty names and contact information was available on the school web site of each building within the district. I looked on the school web site to identify the grade level of the participant and to see if I could determine if science was part of their teaching assignment.

Participants who responded to the email invitation were sent a follow up message to verify they met the inclusion criteria and to provide a copy of the consent form for their review. Participants were asked to suggest via email an interview time and location. Five teachers expressed interest initially, received the consent form but then declined to be interviewed, citing that they felt they did not know enough to contribute to the study.

Participants who agreed to be part of the research study selected the time and location for the interviews. Interviews were eventually conducted with eight elementary teacher participants as well as with five administrators. The semistructured interview protocol provided the prompts to construct the direction of the interviews and to ensure alignment with the research questions. The open-ended nature of the semistructured protocol created entry points for the participants to expand upon their personal experiences. During each interview, I made notations of significant comments. These comments struck me as powerful, either because they strongly expressed an experience that had been identified as significant during the review, or alternatively if the comment was unexpected, I also made a notation during the interview. An example of a significant comment provided by Ann was that she “could not identify any of the topics that she would be teaching in the upcoming year.” She also “apologized for the reliance on Pintrest as a resource.” (Pintrest is a free website that allows users to upload, sort, and manage pictures or information on any topic of interest. There is no oversite or vetting of accuracy or quality within Pintrest, and it is not limited to education topics.) Ann knew that her approach was not the best approach to accessing new content, but I appreciated her honesty. An additional significant example of a comment that I made note of during the data collection was by Ann. Ann indicated during our engineering concepts discussion “that any problem, such as what to wear when it is raining, represents an engineering challenge." This description of an incorrect example demonstrated a lack of understanding by Ann of basic engineering concepts that are to be taught at the elementary grade level.

Ann also commented that reflection was an important part of the process to evaluate if students understood the lesson. She did not, however, include her own evaluation of student work as an important aspect of this review. Ann commented that she relied on "crazy looks" as an indication that she may have to revisit a topic.

Chris made significant comments that seemed to contradict each other in meaning, and I used several follow up questions to clarify her intention and aim. For instance, Chris indicated that she "did not think it was effective to rely on the textbook for planning but that she relied herself on studying (in books) anything she could get her hands on to learn about new topics." Chris acknowledged that the biggest challenge to her teaching would be "to not rely on the textbook." This challenge existed in contrast to her own personal learning style. An example provided by Chris for clarification emerged when she described a time when she "wanted to learn more in-depth content within mathematics" and she subsequently took graduate level coursework. Chris did indicate "her interest in learning new science did not rise to the level of taking formal classes, and that workshop experiences that were hands-on had been helpful to learn science." Another participant, Danielle, as well as Chris, indicated that for new topics, they preferred hands-on experiences as a strategy to introduce students to a topic but later indicated they both relied on what children will be reading from the book as the main guide for classroom planning and instruction.

Immediately after each interview I documented my impressions of the interview and created a summary document within my researcher log. An illustration of a significant outcome of these summaries was that I was able to use the common descriptions from teachers to identify the existence of the theme that teachers do not feel supported by district level administration. After reviewing my summary logs, I noted that Anne, Danielle, Gina, and Helen explicitly mentioned they do not feel supported by “the system.” My overall impression was that teachers feel isolated within their own classrooms and in their own approach to learning and that these aspects should be explored at a deeper level in the analysis.

Another example that emerged from the summaries was that many of the teachers, Ann, Chris, Danielle, Fran, and Helen, for instance, could not articulate in detail what topics they were going to be teaching in the upcoming year. This indicated to me that there is a lack of understanding on the teacher level of the changes that are associated with the NGSS, and there is a lack of understanding of the content of the science and engineering concepts. Only Betty made specific connections to the NGSS standards and though she “acknowledged [she] needed to spend time reviewing standards and topics this summer,” she described how the NGSS would inform her planning for the upcoming classroom. Betty was also the only teacher interviewed who understood that engineering is now expected to be integrated into the science domains at each grade level.

The researcher log also contained information I noted about nonverbal cues and overall tone during the interviews. All of the teachers appeared confident that they were going to be prepared for the school year. This surprised me, as many of the teachers, Ann, for example, could not identify any of the topics that were part of the curriculum. Other teachers were very vague in their identification of topics they would be teaching, providing superficial labels that corresponded with the major topics found within the NGSS. As the researcher, I struggled with how to probe for follow up understanding. It became apparent that there is lack of content understanding of both science as well as engineering concepts from many of the participants. I used this insight that emerged from the researcher log notes to focus the analysis on how participants approach learning a topic. I did not focus during the analysis on a possible alternative route of how participants determine grade level alignment or how the concept that is called for at each grade level fits within the larger learning progression. What became apparent after reading the summaries of the transcripts that I created after each interview is that once teachers enter the classroom, their professional learning of science and engineering becomes limited in formal settings.

Many of the teachers, when prompted about what was lacking in their teaching, did not focus on content knowledge. I initially anticipated that teachers would identify units or concepts that needed deeper understanding as the teachers could not clearly articulate what topics they would be teaching, The teachers interpreted the question as what was lacking in resources at the building or district level and described their needs as they were related to materials or other resources. Teachers did not discuss needs within the context of their own competence. These comments informed my analysis approach by refocusing the question of teacher needs to center on the external factors that impact learning, in this case building and district level supports.

Each interview lasted approximately one hour and was recorded by two digital devices. I transcribed each interview verbatim into a word document and sent the transcription to the participant for member checking. Due to the rich discussions during the interview, one variation in timing did occur. The transcription of each interview took longer than 1 week to complete, and this extended the timeline beyond 1 week to get the transcribed interview to the participant. All transcriptions were completed within 2 weeks of the interviews. The transcribed interviews ranged from 10 to 19 pages in length for the administrators and from 12 to 22 pages in length for the teacher participants.

One administrator provided additional examples to supplement the interview data information. These examples related to one of the interview questions, and I printed out the additional information and attached it to the transcribed interview. One teacher altered the word choice in one of the sections to better reflect his experience during the member checking process. All participants did confirm the interviews reflected their understanding and experiences of professional learning and expressed appreciation for the opportunity to participate in the study. All participants were thanked for their participation in the study, and as per the study invitation, received a $25 gift card as consideration for their participation.

Data Analysis

The analysis method that I applied included a multiple-stage approach to the examination of data. I read the transcripts and researcher log notes multiple times and generated memos related to insights that emerged where I recognized connections between participant descriptions and the ideas of reflective learning and sensemaking. An example of an insight generated was the connection made between the varied descriptions from participants which exemplified sensemaking activities. Gina, Fran, Jordan and Betty articulated how they use the internet to better understand a topic by either googling the title, entering a specific question, sifting through Pintrest sites, reviewing lesson plans or looking at science resources. The range of descriptions included hands-on activities to make sense of concepts as well as seeing grade level examples of lessons as a way to understand what a concept presents as at grade level. Participants also gave varied descriptions related to the benefits of university led professional development. Betty, Chris, Fran, and Danielle each made comments that led to the generation of a memo which noted that hands on experiences led to a deeper understanding and could be classified as a form of sensemaking.

During the initial round of analysis, I utilized provisional starter codes that align with the reflective learning theory work of Schön (1987) and the sensemaking constructs of Weick (1995). The starter codes encompassed attributes of learning such as hands on experiences for learning within science, reflection, and peer collaboration. The starter codes also included workshops and support from sources such as coaches. Based on the literature review I also identified provisional codes to represent barriers to learning such as the codes of lack of resources and time at both the individual teacher level and district level. Conflicting external priorities with an emphasis on language arts, mathematics and state mandated testing in these areas were also included in the initial rounds of coding.

The next step included open coding in the subsequent rounds of analysis. Open coding identifiers emerged from participant experiences and reflected the variations of participant descriptions that related to their approach to learning. These additional codes emerged as a result. These open codes included internet usage, informal peer collaborations and formal strategies of professional learning communities and grade level meetings. The presence of higher education support also developed out of open coding procedures. The transcripts were examined and excerpts that contained relevant concepts were marked in the text. This approach mirrored the responsive interview approach described by Rubin and Rubin (2012).

To capture the information within a code that was identified I created a separate index card for each example. The index card contained the participant identifier, source of information (transcribed interview or researcher log or memo), the code label, the example and the location of the example such as the page number. The use of the index cards was essential for the analysis step of comparison of coded information, not only within interviews but across the interviews as well. The codes could be physically sorted together and those that repeated within the sorting and grouping became the themes that I used to describe the participants' approaches to learning within the context of the new standards of the NGSS. This responsive approach to the analysis allowed coding across the interviews, and the index cards with the same codes could be sorted into physical groups and reviewed and summarized. Within each new group, I sorted and resorted the cards. This created the opportunity for comparisons within excerpts and creation of subgroups, as recommended by Rubin and Rubin (2012). The summaries I created from each sorting were weighted and integrated into a complete picture of the participant experiences.

To further strengthen this analysis strategy, InVivo coding was applied to the interviews. The use of computer software as an analysis tool added more detail to the description by revealing repeating participant language. I used the word frequency tool to recognize patterns and to confirm the codes and themes that I had previously identified (Miles et al., 2014).

Peer debriefing was also utilized to engage in discussions with a colleague and process the emerging themes. An example of how I used the peer debriefing occurred in discussions that identified the competing priorities that teachers deal with and make decisions based from. I discussed with a colleague the meaning of statements that encompassed how teachers viewed resources such as the text book, curriculum pacing guides and district mandated quarterly assessments. Teachers such as Fran said they "go by the chapters, only do engineering in Chapter 2 because that is where it is presented in the textbook." With quarterly assessments that are aligned to the textbook this lead to the circumstance that engineering understanding was only assessed during the first benchmark assessment. There was no mandate by the district, reflected in quarterly assessments, to assess again and this conveys a priority to the teachers about the values of the district. Ann, Gina, Jordan and Chris explained that they teach engineering in Chapter 2 because that is where it is in the text book. Danielle expressed frustration because she recognized that competing priorities were in conflict with each other. Danielle expressed these priorities as the textbook, quarterly assessments, state testing, and standards. Discussing with my colleague helped me to identify that the teachers had a range of ways that they expressed what influenced their planning and teaching and that the text book was a main source for curriculum decisions about what to teach.

The emerging categories or themes became the framework for the analysis and they reflected the work of Schön (1987) and Weick (1995). The analysis embodied the factors contributing to adult learning as put forth by Schön (1987) and Weick (1995). These influences emerged from the contextual descriptions provided by participating teachers when identifying how they approach learning in new contexts, in this case the NGSS.

A technique of explanation building as a process was used in the analysis (Yin, 2014). I employed the schema related to adult learning that supported the research inquiry to make connections to phenomena described during the interviews. Similarities to a spiral data analysis as described by Maxwell (2013) are evident. These similarities included the organization and processing of the data and the application of provisional and open coding into groupings that align with the constructs of Schön's reflective learning theory (1987) and sensemaking (Weick, 1995). The constructs ranged from job-embedded learning, reflection, and connections to prior knowledge, and also included motivation and peer learning as relevant subsets that supported the construction of the final narrative. The final narrative, described within the results section, illustrated the perceptions of needs for learning as described by the teachers and administrators in response to the NGSS. This narrative reflected the identified opportunities and barriers to learning that exist within this group of in-service teachers. The voice of the administrators represented the structures within the education system that had an impact upon teacher learning at both the building level and throughout the district. The limited role of the administrator as an instructional leader emerged. The constructs of reflective learning and sensemaking created a lens to view the participant experiences through and to discuss the supports and barriers to learning for in-service elementary teachers.

Evidence of Trustworthiness

To strengthen the trustworthiness of this qualitative study I employed multiple strategies to address issues of credibility, dependability, transferability and confirmability. I used approaches advocated by Rubin and Rubin (2012), along with those of Miles et al. (2014) that led to specific steps integrated within the data collection and analysis aspects of the study that specifically addressed issues of trustworthiness. The following subsections address how I used strategies appropriate for qualitative research.

Credibility

Credibility issues were addressed during the research planning and implementation of the study and were aided by the use of explicit protocols. Internal validation was promoted through thoughtful participant selection. The participant selection process I used selected interviewees who had first-hand knowledge of the phenomena and who were able to represent varied experiences with the phenomena of ongoing learning in response to the NGSS (Rubin & Rubin, 2012). To enhance credibility, I relied on member checking as an essential component for processing the data (Miles et al., 2014). Each participant was provided verbatim transcripts of the interview sessions and summaries of the study to review and comment on. Participants were asked to make any changes necessary to reflect their voice accurately. I also relied on saturation of data to strengthen the credibility. Reaching saturation with the data collection supported the confidence in the conclusions drawn and was an effective strategy to integrate into the research design.

Dependability

Dependability ensured that the research study occurred with consistent attention over time to maintain integrity in the research and its conclusions (Miles et al., 2014). The dependability or reliability of research can be addressed within an interview study with data collections that result in rich, thick descriptions. Using semistructured probes during the interviews created the avenue for each participant to answer questions that ask for elaboration as well as clarification of evidence related to the phenomena (Rubin & Rubin, 2012). The approach of semistructured probes allowed me to address questions tied directly to the research questions as well as have open space for participant elaborations or varied experiences. To add to the dependability of the study I engaged in a reflexive approach to reviewing the interview transcripts and in the audit trail that I created. The trail enhanced the documentation produced and self- monitoring, and prompted me to consider alternate interpretations of the data.

Transferability

The strategies of open probes and broad, thick descriptions also supported attempts to increase the transferability within the study. The use of variation was also essential to enhance the transferability within this interview study. Within the participant pool of elementary teachers, the interviewees represented a range of not only grade levels of experience but also years of teaching experience. Study participants also included administrators to enhance the detailed descriptions of the phenomena of continuous learning within the school setting. My descriptions of the results within this study provided a comprehensive overview of the experiences of the elementary teachers within this urban school district as they respond to calls for new learning related to science and engineering within the NGSS.

Confirmability

Confirmability was addressed with my attention to an objective approach within the study. I articulated the methods and procedures to be clear with the data collection and analysis approach and to minimize the impact of researcher bias. I used reflexivity throughout the analysis, and used a researcher log to document reflections and insights. My own experiences as a teacher and professional development provider may have influenced how I have perceived and interpreted the data. Actively considering alternate interpretations and explanations became an important analysis strategy that I used. Considering and acknowledging the possible influences as factors in the study strengthened the confirmability of the research and the conclusions I reached.

Trustworthiness was further developed with the proper alignment to IRB protocols. A letter of cooperation was obtained with the target district prior to any data collection. I also took a systematic approach to the recruiting process to support the participant selection. Informed consent was obtained from all participants prior to any of the interviews and the study goals and consent process were reviewed with each participant in person again prior to the start of the interviews. Results of the interview analysis were presented in relation to the research questions in the following section.

Results

The eight teacher participants and five administrator participants provided rich descriptions in the sections below of their experiences with the supports and opportunities as well as the challenges associated with pursuing understanding of science and engineering concepts in response to the NGSS. The descriptions of this understanding emerged as they relate to both personal understanding and the underpinning goal of translating this understanding into classroom practice. The supports and barriers at individual and group levels within a building setting and within a district emerged as dominant themes and are described from both the perspective of the participant teachers and administrators. Teacher perceptions of how to strengthen professional learning opportunities surfaced throughout the discussions. Table 2 provides a summary of categories and emergent themes. The categories represent the broad groupings of responses that aligned with particular research questions. The first research question was, "How do elementary teachers perceive their needs for learning new science and engineering content knowledge and acquiring pedagogical content knowledge for teaching in response to NGSS reforms?" Participant responses were grouped into the category of stimulus for learning to capture the range of how teachers described their needs for new learning. Two main themes, *motivation* and *preparedness,* emerged from the analysis of these responses and were grouped under the category of stimulus for learning.

The first subquestion—"What strategies do elementary teachers perceive would provide support for learning new content and developing pedagogical content knowledge?"— allowed for a deeper examination of approaches to new learning by having participants identify specific approaches they have used. The responses were grouped into two categories which were inclusive of all the responses related to the question. One category I identified was informal strategies for learning and included approaches that teachers utilized on an independent and frequent basis. These responses were ones that were not directly provided for by the district and were initiated by the teachers on their own volition. Themes which emerged from this category included the use of the *internet* and informal *collaborations*. A second category for subquestion 1 was formal supports for learning that were described by the teachers. These formal constructs are designed by the district to promote learning opportunities for the staff. Themes of *mentoring*, *common planning time*, *professional learning communities*, *grade level meetings*, and *university led professional developmen*t described the participants' experiences with these potential supports for professional learning.

The second subquestion—"What do elementary teachers perceive are the barriers and challenges to learning new content and pedagogical content knowledge regarding NGSS?"—informed the development of the fourth category, formal barriers to learning. The category developed from participant answers identifying structures that limited teacher learning of new science and engineering concepts. An examination of the participant responses within this category led to the identification of several themes, including *professional learning communities, faculty meetings*, *grade level meetings,* and *curriculum and assessment barriers*. *Priorities* and *resources* also emerged as important themes related to teacher perceptions of barriers to learning of science and engineering.

Remaining needs also emerged as a final category, which included barriers to learning new science and engineering concepts. A lack of *content knowledge* and *pedagogical content knowledge* were themes that described the remaining needs of teachers in the study.

Research Question 2— “What do administrators believe are the barriers and challenges to implementation of mandated NGSS?”— prompted responses from administrators that were able to capture the perceptions of barriers to teacher learning from the perspective of district leadership. The responses were grouped into the category of administrator formal barriers because they reflect the constraints that exist within the school system at either the building level or district level that hinder teacher learning. Themes of *time to prepare*, *materials*, and the *role of the administrator* emerged as themes within this category. Table 2 summarizes the categories and themes which emerged from the analysis of the interview data and that align with the research questions.

Table 2

Emergent Themes and Categories

Category	Themes
Research Question 1:	
Stimulus for learning	*Motivation*
	Preparedness
Subquestion 1:	
Informal strategies for learning	*Internet*
	Collaborations
Formal strategies for learning	*Mentoring*
	Common planning time
	Professional Learning Communities
	Grade level meetings
	University led professional development
Subquestion 2:	
Formal barriers to learning	
	Professional Learning Communities
	Faculty meetings
	Grade level meetings
	Curriculum and assessments
	Priorities
	Resources
Remaining needs	
	Content knowledge
	Pedagogical content knowledge
Research Question 2	
Administrator formal barriers	
	Time to prepare
	Materials
	Role of administrator

Research Question 1

RQ 1: How do elementary teachers perceive their needs for learning new science and engineering content knowledge and acquiring pedagogical content knowledge for teaching in response to NGSS reforms?

The construct of continuous learning framed the interviews and what emerged as a leading theme throughout all discussions was the motivation that drives the learning and the connection to being prepared for the classroom. For the participating teachers, this was captured in the two themes expressed as *motivation* and *self-efficacy*. Evidence of varied expressions of motivation were all framed around an awareness of a change in expectation of what was to be taught in the science portion of the classroom in response to the NGSS.

Motivation. The participant teachers who were interviewed were aware that the state and district had adopted the NGSS. The participants understood that these new standards required a change in what was to be taught, and the varied responses to the new demands will be elaborated on within explanations of supports and barriers. As described by Fran, "NGSS will force reflection on what we know." The participating teachers expressed an understanding that there will be changes to the scope and sequence of the curriculum at each grade from kindergarten through sixth grade.

A highlight from the participant responses that was consistent throughout the interviews was that the adoption of the NGSS provided motivation to engage in new learning. Many of the teachers related that deepening their understanding of the NGSS would better prepare them for the classroom. Chris explained that learning more about the NGSS "would help me be better prepared for the kids." Changing standards can even be a reason to go back to school, as Chris did for mathematics. Upon further probing, however, Chris indicated that there must be a deep personal interest by a teacher to achieve the level of commitment required for returning to school to learn more content; regardless of the standards at the district in which the educator is employed. Jordan commented that "seeing the student reactions to doing science, their increased excitement, made me realize I needed to learn more content." As a novice teacher, Jordan said that it was not until *doing* science in his first year that, "I realized I needed to learn more about teaching science." Many of the teachers appeared confident during their interviews that they felt they knew quite a bit of science already. This confidence contradicts the explanations for motivation and preparedness that emerged from the teacher interviews, and is in contrast to research evidence related to the minimal formal training in science that elementary teachers' preparations.

Jordan's experience in realizing there was a need to learn more about teaching science was not unique. This disruptive experience of science within the classroom was also described by Fran who expressed motivation for learning new content for the NGSS so that she "would be able to answer questions from the kids." Ann also articulated this desire to be able to answer student questions. However, Ann described how the new or challenging questions often came up during class time and that she would work with the students to look up the answers in real time. Ann noted that reflection was often needed *after* class to put the experiences into the context of the kids' lessons. Ann recognized and expressed the value of taking the time to reflect as a means to increase her effectiveness in the classroom. Fran also discussed that “being prepared for the kids was a motivation for learning and that to prepare it (it) was important to think about it.”

Many participants described their method to classroom instruction planning as a motivation for learning more about the changes within the NGSS. None of the teachers or administrators interviewed could identify the specific science or engineering topics they were expected to implement for the upcoming school year. This trend presented a serious concern about the level of understanding they possessed of the NGSS; of the changes it advocates related to content, practices and connections among domains.

Gina explained that before taking time to learn about new topics or activities, she “considers if it will be engaging to the kids.” Gina clarified this comment by further stating that she was able to evaluate a lesson’s effectiveness if an activity component was added to it. Gina prioritizes the hands-on component of the student experience and this becomes a prominent element in selecting topics to develop further understanding within the subject, with the intent of supporting instructional planning and implementation. Danielle also expressed a similar motivation when describing her approach to learning, making it clear that “I like hands-on lessons and I like when it is fun.” Chris extended this idea explaining that a motivation for “attending workshops is to get ideas for lessons and activities in the classroom because it provides examples for the classroom.” This notion of relating job effectiveness as a motivation to the learning of new content or strategies emerged as a strong theme within the analysis.

Additional reasons that drove the desire to learn new science included Helen and Gina’s descriptions of personal interest in a topic as a motivation to discover more about specifics, regardless if it was called for within the NGSS. The call for professional responsibility was also articulated by Jordan. While not explicitly stated by the other teachers, all conveyed a sense of professionalism in their approach to their performance, guiding their desire to be prepared in the classroom. Helen captured the sentiment with the statement "I can best get myself ready and can figure out what to do with the kids. The key is engagement and my experience tells me what is best for kids at this level."

In summary, the participating teachers recognized that changes advocated within the NGSS represent a shift in instruction either in regard to science or engineering content understanding or possibly to the approach to instruction. Participants are unlikely to be familiar with the new content in science and engineering that is expected to be taught in their classrooms. As noted in the interviews with Ann, Chris, Danielle, Fran and Helen, the participant teachers were not able to identify or articulate specifics information about the new content the teachers are now required to present to students. Teachers did not seem concerned with this lack of knowledge and may represent the notion that they did not know what they did not know. Participating teachers considered this lack of knowledge as temporary and focused on the context of how it affected their preparedness for the classroom. This need to be prepared served as a motivation to pursue additional professional learning opportunities. As exemplified by Fran's remark "being prepared for the kids was a motivation for learning, and that to prepare for it (it) was important to think about it." The goal of being *motivated* for these changes in the classroom resonated as a common theme amongst the teachers. As voiced by the rich descriptions earlier from Jordan, Fran, Chris and Ann, the connection between motivation to learn and supporting students in the classroom was strong among the participants. The desire to provide hands-on learning experiences for students and the ability to answer student questions emerged as top motivations to drive continued learning for the teachers.

While all the participants identified being motivated to learn new science or engineering as a need to support preparations for the changes associated with the NGSS, there was a range of how well the participants described their level of preparedness going into the upcoming school year. Preparedness emerged as a theme related to implementing NGSS.

Preparedness. Several participants identified that they would feel more prepared, and would increase their effectiveness in the classroom if they could engage in hands-on learning themselves. Fran identified hands-on workshops as critical to becoming prepared for the upcoming school year. Danielle further expanded on this same benefit of being prepared through the experiences of hands-on workshops. Danielle articulated that “you feel more prepared when you see concrete examples,” and that this helps you in the classroom. Danielle further explained that being prepared would increase with a buildup in background content knowledge of both science and engineering. Chris reinforced this theme that being prepared increases with hands-on workshops when she described these experiences as facilitating a better understanding for herself. Helen indicated that “hands-on experiences increased the sensemaking of the concepts” for both herself as well as her students. Chris also connected the concrete examples as critical to identify what you should use in class. Additional participants, including Fran, Ann, and Gina, echoed the sentiments that hands-on experiences would increase preparedness in the classroom.

To summarize the level of *preparedness* theme that teachers described, Ann, Gina, and Helen felt they were not prepared for the changes associated with NGSS, as evidenced by their respective responses. Gina described her current level in the following answer. “I know that there’s changes in topics, and it’s set up in a different way, but as far as the ear of it, I’m not anywhere where I need to be in order to be able to do that”. Helen remarked “I don’t even know if the curriculum has been revised. There’s teachers who don’t even know it’s coming.” Ann captured the importance of the hands-on aspects of the NGSS in her remark “I am not nervous about the new content, but about getting the hands-on,” Understanding the connections between the content and the experiences within hands-on activities reflects the depth or lack of understanding of what the changes in the NGSS represent.

Betty, Chris, and Fran described that they were adequate in their level of preparedness. Betty noted that while she herself felt prepared, “I really need time and pacing, you never know what’s going to hit you.” Danielle and Jordan described how they were somewhat prepared and that their preparedness would increase with the workshop experience. All participants gave the impression that they would be able to learn what they needed to be prepared to implement the changes within the NGSS. Participants articulated a range of strategies and supports that would be necessary to meet the increased demands of science and engineering understanding associated with the NGSS.

Related to the first research question are sub questions that further describe perceptions and categorize them into strategies for learning or barriers to overcome which impact learning.

Subquestion 1

What strategies do elementary teachers perceive would provide support for learning new content and developing pedagogical content knowledge? The participant responses can be described at both the individual and group level, within the building and district settings and through both formal and informal channels.

Several themes emerged when examining teacher perceptions of supports for on-going learning approaches that were both informal and formal in nature. The informal strategies for learning revealed themes such as utilizing the *internet* and *collaborations*. Identification of multiple supportive strategies highlighted the varied entry points for continuous learning for in-service teachers.

Internet. All participating teachers identified the internet as the initial resource that they rely on when it comes to learning new science or engineering. Technology support was identified as accessible, reliable and the most common first step by the teachers. There was a range of reports however as to how or why online resources were utilized. Only two teachers, Fran and Betty were explicit in their description of how they used the internet to specifically research NGSS standards. Betty was familiar with NGSS sites that provided explanations of content as well as examples of lessons for implementation. Betty remarked that “I go to the NSTA site [National Science Teachers Association] and to the state NGSS site and lean in the direction that they are going.”

Betty also shared that she used these sites to deepen her own understanding of new content.

Jordan described the use of the internet as a learning approach that helped process information for their own learning. When looking at resources Jordan explained that the approach is to adjust what you find online and "make it ready for the kids." The end goal of using the concept in class appears to be the desired level of understanding that many of the teachers reach for. Comparing online resources as a refresher to what Jordan has previously learned from hands-on professional learning experiences were key to his getting lessons ready for the classroom. Googling the topic was also a part of Jordan's strategic approach. Valuing resources that are associated with whom Jordan recognized as reliable sources such as Bill Nye or Brainpop was essential to his searches. Chris also articulated that while the internet was the main research tool, which web sites to look at first or prioritize for learning was not an area of confidence. Danielle and Gina described the online text resources that were available to them as a helpful.

Helen, Gina and Fran also identified the internet as the primary resource for learning new material. Helen summed up her approach with "I go to Google." Gina also remarked that "I will look for online materials, I google stuff." Fran and Gina rely on the Google search engine to review material in a way that Fran explained as "putting my exact thoughts into google and seeing what I get." The main resources on the internet used by Gina, Ann and Helen were Pinterest and Teachers Pay Teachers. When asked if they had strategies to vet the resources found on these two sights, the teachers were unable to provide a rationale that was research based or strongly aligned to NGSS goals beyond a surface level. Jordan noted that “when I have to start researching for a new topic, I begin with googling lessons to see what might be good for the kids.” The ability to assess the quality of resources appears to be lacking. Helen articulated her thoughts in a way that exemplifies the participants approach to using the internet “that relying on online sources may not be the best strategy for learning new science or engineering but that it is the most readily available one.”

Collaboration. Many of the participating teachers also described the strategy of informal collaborations as essential to extending their knowledge and enhancing their ability to be prepared for the classroom. Interactions that were spontaneous or not directed by an administrator but initiated between teachers were grouped within informal collaborations. These interactions could occur during the school day or extend to after the formal school day hours.

Helen observed that peer learning between grade level partners extended understanding in directions for “what to do and what not to do in the classroom”. Helen made this comment in response to the query of how effective she felt collaborations with grade level partners were in support of teacher or student learning. One partner relied solely on the textbook and did not incorporate any hands-on activities into her lessons. Helen felt “the students did not have a positive experience in this type of learning environment” and disagreed with her colleague’s approach to instruction. “I can’t plan two weeks in advance and she plans two months ahead!” remarked Helen about the challenge with planning a science lesson. Helen was explicit that this type of instruction was a model of what not to do, and that it contradicted what she knew as effective science instruction.

Betty described the informal collaboration that occurred within her building as helpful and an occurrence that often extended across grade levels. While formal mechanisms are set up to facilitate collaboration once a month, informal interactions occur daily for Betty. Betty remarked that “I can always talk to colleagues in the hallway, and it doesn’t matter if it is a fifth grade question or a middle school one.” Ann also expressed that peer support was a valuable resource for professional learning. Ann illustrated that this interaction could be in the hallways, after school or through email. As the latter extends interaction beyond the school day as many teachers communicated via email after school hours. Betty also noted that email was a common mechanism for the interactions, remarking that collaborations were not limited to in person conversations. Ann noted, “We are our best resources.” This comment reflects the dependency teachers have on each other for support.

Chris and Fran had contrasting experiences relating to the informal collaborations around their schools. Chris explained that an increase in contact time between colleagues was due “to the friendly relationships generally existing between the teachers” and that professional learning did take place. Fran however felt that informal interactions were in fact friendly communications only and were not professional collaborations that ultimately led to deeper understanding of content or improved instructional capabilities. Fran believed formal mechanisms were more effective in supporting professional learning within the building and district. As Fran remarked “I think people tend to work with their friends as opposed to their professional colleagues in the sense of professional support." Of interest is that participants who are the sole providers of grade specific science in their respective buildings such as Jordan, did not identify any informal collaboration as part of building interactions which resulted in professional learning. It is apparent that social relationships in the work place have an impact upon the experience of the personnel. These relationships can be formal in nature as well to support ongoing learning for elementary teachers.

Mentoring. Formal supports have been put in place to encourage professional learning of all teachers at the building level as well as throughout the district. These formal supports include small and large group settings to support learning. Betty identified the mentor relationship between novice and veteran teachers as an effective strategy to support growth. Betty, as a twenty five year veteran, served as a mentor multiple times. It is noteworthy that none of the participating teachers that have under five years of experience identified the mentor relationship as an important factor in their development of science or engineering understanding.

Common planning time. Chris was the only teacher who specifically identified common planning/preparation time as a support provided by the building administrators to promote collaborating with colleagues. Chris noted that this common planning session only occurred once a week. Danielle described the common preparation time indirectly with the description that there was time during the school day for teachers to meet and plan together. The other teachers interviewed did not identify a common planning period as a strategy that promoted their own professional learning.

Professional learning communities. Another category associated with learning that was identified by the participant teachers was termed a "professional learning communities (PLC)" and it exists at the building level. The PLC support is an intentional strategy from district level leadership that has been put in place to support professional learning within each building. The PLC composition is influenced by the building make up as some teachers may be the only science teacher at their grade level or there may be multiple science teachers within the grade level and building. Therefore, there may be horizontal or vertical PLC groups that focus on science or other subjects within the buildings. These PLC meetings occur once a month as part of larger faculty meetings within each building. Danielle described PLC meetings in her building in the following manner "If at the faculty meeting, there's less to discuss like mid-March and there's not much going on, there's no assemblies, whatever and we covered everything in 20 minutes, then she'll say the last 30 minutes, 40 minutes , go in your PLC's and just take care of whatever you need to take care or finish up this paperwork because you know it's due next week, so then we just go and do that. That becomes very informal, sometimes becomes a bitch session, you know how that goes." This illustrates how the PLCs themselves did not have a specific curriculum to follow. The teachers within each PLC determined what the focus should be for the meetings. Betty commented that "in my experience this past year, my meetings didn't really occur or they were cancelled because there were other priorities. There was a great emphasis on PARCC [testing for language arts and mathematics]."

Teachers did not provide specific examples of what they have learned within the PLC meetings though many identified them as a potential support for growth. In contrast, one teacher, Fran felt they were not effective to promote learning. Fran remarked “that there was an assumption of science understanding among teachers that correlated to the grade level of teaching assignment. The level of understanding was expected to be at the grade level that you teach.” This assumption of depth of knowledge limited collaboration opportunities within PLC meetings because, from Fran’s experience, colleagues assigned to higher grades did not want to discuss science with Fran.

Grade level meetings. District level meetings are held three or four times a year for grades four, five and six. Kindergarten through grade three do not have these meetings as they are under the direction of early childhood and do not work directly with the supervisor of science. The district level grade meetings bring together the teachers who teach science at a particular level. These teachers may teach only science or have additional assignments during the day such as mathematics depending on the needs of the particular building they are assigned within. District level grade-level meetings are facilitated by the district science supervisor, who sets the agenda, facilitates, and collects feedback from participating teachers. The science supervisor has used the grade level meetings to roll out information related to the NGSS. Betty remarked that the “district did bring up the NGSS. There was a training done, and it was an introduction and there was a matrix given.” Danielle stated that the new standards “were mentioned by the supervisor at the meeting.”

Meetings have similarly provided professional development experiences for teachers which were facilitated by university level professional development providers, recognized for their work with the NGSS. All of the teachers identified the grade level district meeting as a potential source of learning, though only the meetings which contained the university professional development were identified as meaningful. The difference in agenda and focus of the meetings may account for the variation in perceptions of effectiveness. Ann described the meetings as “sometimes going through paperwork.” Meetings which were focused on the logistics of testing, discussing feedback on data or reviewing timelines for changes in curriculum were not identified by the teachers as factors in their own professional learning. Teachers also compared science grade level meetings to those in other disciplines and spoke of the contrast in effectiveness of support at the grade level meeting when compared to what they have received from other disciplines. Danielle remarked that the math director plans for meaningful engagement with content in the following remarks “we have outside support come to our meetings, and it has been an excellent resource and some of the best professional development in math that I have had in a long time.” Danielle continued, “It is a good mix of here’s a fun lesson, a fun activity that actually helps you meet the standard, but the kids are having fun and learning, they don’t even know they’re learning.” Danielle commented that she has integrated every example provided from the last three years in the math grade level meetings into her own classroom instruction.

Helen described a similar disconnect with grade level meetings and science content. Helen observed that

> there's a lot of professional development wasted on test prep, testing, Common Core. There's a lot of that. I feel like there's a lot wasted professional development time. The directors know nothing about the subject which they direct. The mentality has always been a little bit that we'll have a random teacher here for early development. It's almost like they really believe that it's babysitting.

University led professional development. Professional development workshops are typically one day experiences that provided hands-on immersions with a specific phenomenon of science or engineering. The alignment to NGSS is typically explicit as part of the workshops and translation of the examples into the classroom is discussed to highlight the concerns associated with implementation. There are multiple local universities in the surrounding area that have provided workshops. Development of the agenda for these professional development days is coordinated through discussions with the science supervisor.

Many of the teachers mentioned that attending the workshops was an opportunity to increase their own learning. Ann remarked that her introduction to the NGSS occurred at one of these workshops. Ann also elaborated that the hands-on aspect of the workshops was important for her own understanding and that she felt this approach, to have hands-on activities, would work for the kids also. Ann articulated that she takes the ideas from the workshops right into her classroom.

Betty remarked that not only did she attend professional development workshops to enhance her own knowledge but what was valuable was the support provided by the university staff. “They make it ok to not know, and you get encouragement that you can do it.” Other teachers including Chris, Jordan, Fran and Danielle likewise identified attending workshops as a source of their own learning. Of note, all of these teachers have participated in additional programs that were coordinated through the universities. Danielle captured the sentiments of the teachers with the statement “the workshops increase your own understanding, and they give you ideas and lessons to use.”

Fran was the only teacher who was explicit in describing the need for these hands on demonstrations for the purpose of learning about engineering. Fran also highlighted the benefit of the professional development workshop setting to support pedagogical content knowledge development. This develops with a focus on the variation of classroom experiences that often occurs. As Fran described, the workshops are “not just transmission of set facts but there are discussions and questions that get you to think about how to use the information.”

In summary, teachers identified a multitude of both formal and informal supports that enhanced professional learning and aligned with motivation and preparedness goals. Informal interactions at the building level such as the internet and collaboration facilitate learning to varied degrees. Formal mechanisms, ranging from PLC and grade level district meetings, to additional university provided workshops, were recognized as critical supports to enhance both content and pedagogical content knowledge for individual teachers at the building and district levels. Many teachers commented on the potential of these settings, and have experienced varied levels of success utilizing the supports. During the interviews teachers also identified barriers associated with the NGSS which have had an impact upon their learning. Related to the first research question is an additional sub question that after analysis further described the teacher perceptions and categorize them into barriers to overcome which has an impact upon learning.

Subquestion 2

What do elementary teachers perceive are the barriers and challenges to learning new content and pedagogical content knowledge regarding NGSS?

Multiple themes emerged when examining teacher perceptions of barriers for on-going learning of science and engineering. These themes surprisingly included barriers to learning at the building and district level that were also previously mentioned as opportunities or supports to professional learning. The barriers included collaborative efforts such as PLCs within faculty meetings and grade level meetings but also touched on curriculum and assessment, priorities and resources, and remaining needs. Competing priorities, an emphasis on data and assessments, access to materials, and a lack of support to obtain new content and pedagogical content knowledge emerged as compelling barriers to professional learning for elementary teachers as they moved towards understanding and implementing the NGSS.

PLCs and faculty meetings. Several teachers commented that while PLC and faculty meetings held the potential to promote professional learning, they themselves did not have positive personal experiences in these settings. Jordan is the only science teacher within the grade level so there is no science PLC in the building. Jordan noted that "PLC meetings at grade level that did occur were focused on math or language arts," and collaboration efforts were limited to these two subjects. Ann experienced a similar focus on math and language arts during her building meetings and noticed “an increased amount of professional development time during faculty meetings dedicated to math and language arts over the last four years.” Betty correspondingly noted that professional learning support was “less for science as compared to social studies and other disciplines.” Gina and Fran likewise indicated that while the PLC’s exist, there are no active ones that support science or engineering. Fran noted that “while in theory there was time for a PLC to meet, in practice, competing obligations consumed the time” for professional learning within the school. Fran and Helen both remarked that during faculty meetings science never comes up as part of the agenda. Danielle echoed a similar experience, sharing that time “within PLC meetings or faculty meetings was not focused on learning, but on providing logistical updates to the faculty.”

A lack of administrator understanding of NGSS was identified as a reason that science is not a priority at faculty or PLC meetings by Danielle. Aligned with this perception, Ann indicated that there was “no one at the building level to direct questions to” and this contributed to a feeling of diminished support. Helen simply remarked “there is no support.” Gina also reported similar feelings of minimal support at the teacher level within the building. Gina remarked “We’re not getting enough direction from the higher levels.” Gina indicated that while this provided a desired level of autonomy, it was also in her experience a source of isolation when it came to professional learning and planning. An example of Gina’s experience can be seen in the remark “I think within the building they would defer to me to use my best judgment to do what’s best for me and to have the autonomy to make the best decisions for my students." Jordan noted that there had never been professional development for science in the building.

Grade level meetings. Grade level district meetings were also identified as barriers due to contributing factors of infrequency, agenda, and communication. This negative identification contradicted other details where teachers expressed the existence of a potential for learning within these periodic sessions. Helen observed that at grade level meetings "we get an agenda and we go through the agenda and that's it. There's no real professional development, there's no discussing things and it just seems like the same topics are brought up over and over again." Danielle stated she did not think the science supervisor, who facilitates the grade level meetings, has a science background. "This is our third supervisor in ten years, there is no consistency," lamented Danielle in how the change in leadership permeates the grade level support. Teachers acknowledged the possibility for learning that existed with these meetings bringing teachers of science from the same grade level together for collaboration. In reality however, the time spent at the grade level meetings was not allocated to individual professional learning but was instead used to passively disseminate information about standards or update the staff on the logistics of testing requirements. Ann expressed that "quarterly meetings were very detached from the daily classroom action and she did not feel supported." Gina identified the "low number of grade level meetings, three or four per year, as a contributing factor" to their ineffective nature as a source of meaningful professional learning. Gina commented that with so few meetings "what happens is we get an agenda and we go through the agenda and that's it. There's no real professional development, there's no discussing things and it just seems like the same topics are brought up over and over again." With so few interactions during the school year, many topics needed to be revisited and time was not used effectively.

The facilitation of the grade level meetings was also characterized as a barrier. When Danielle and Ann described how they were introduced to the NGSS at the district level, both commented that there were "no hands-on experiences" and that the passive nature of the meeting did not support any learning during that critical time. Betty exemplified the participant views of the challenges with grade level meetings in her remark "there's not a connection from the department to what has to be implemented." As Betty further explained, "In my opinion, there is a resistance to actually understanding what those standards are. It's almost a bugaboo, It's almost like oh, it's the Next Gen, it's so serious and we have to throw a lot of money at it." The lack of professional development which focused on content and pedagogical content knowledge development emerged as a barrier reported by most teachers. In expressing these concerns the teachers identified what was lacking in their experience, for proper implementation of the NGSS.

Curriculum and assessments. There were many competing priorities that possibly undermined district goals. Teachers were encouraged to begin implementing the new NGSS in their classes but did not receive clear guidance as to a curriculum plan. Gina observed that she received contradictory information related to the curriculum, "I thought we were getting new curriculum, but then someone on the committee told me everything was being redone." Betty, Jordan and Gina all articulated a sense of disconnection between the needs of the elementary teachers and students and the approach by and expectations of, the building and district leadership. Betty highlighted that “according to the NGSS we should have engineering throughout the year, but our benchmarks will only ask about it during the first test.” Betty also expressed concern that many teachers throughout the district will “only teach it in the first marking period because it is in chapter two.” Teachers also noted that they were required to give benchmark assessments that were aligned to the one common resource, a workbook, and a scope and sequence that was outdated. The workbook and NGSS standards were not fully aligned. While the science alignment varied by grade level, the engineering concept alignment typically matched less than 30% of NGSS standards across all elementary grade levels. An additional priority was that these assessments had an impact upon teacher performance evaluation scores.

Priorities. Teachers identified the role of leadership and the communication of priorities as a limitation to professional learning. Administrators at building and district levels prioritized other subject areas, specifically math and language arts. These two subject areas are the cornerstone of the ESSA and yearly measured progressed in these areas in grades 3-8 is mandated at the federal level (U.S. Department of Education, 2016). The focus on data associated with these subjects dominated faculty meetings, professional development and the allocation of time and material resources as described by Betty, Danielle, and Gina. Danielle expressed her frustration with these competing priorities when she stated “I feel like right now I have four bosses and they’re all telling me a different story. They’re all telling me to do something different and its darts at a board. If I hit the mark great, but I’m not sure I’m even hitting the mark.” Danielle captured the effect of the shift in district culture with the comment “that too much emphasis on data has had a negative impact on teacher identity with increased stress and judgment.”

Participating teachers also felt that elementary science was not a priority for the district. The structure of leadership and the nature of the distribution of guidance to kindergarten through grade three isolated these elementary grades from the others in regard to dissemination of information and training. As Helen remarked “It’s almost like they really believe that it’s babysitting.” The end result was that many lower elementary teachers do not cover all the topics required, or at a sufficient depth.

Upper elementary teachers noted that they must “make up” instruction that should have been provided in lower grades. Gina expressed frustration at this reality. “A lot of times I feel like I am starting from scratch because I find that a lot of my students have no foundation skills at all when it comes to science, so they’re really not able to articulate the basics when we start a topic.” Gina speculated the reason why science is not a priority at the elementary level is because “it’s not a tested subject, and there’s so much involved and so much emphasis on test scores, test scores, test scores.”

Resources. All the participating teachers classified the scarcity of time and materials as a significant barrier to their professional learning and implementation of the NGSS. Limited building budgets hindered teachers’ ability to obtain needed materials to provide the hands-on experiences for themselves and students, a critical component of the learning experience. Ann remarked that even basic resources were not available in her building, “I don’t have a teacher’s manual for the science, and can I get one?” This frustration reflected the sentiments of the participating teachers in regard to their experiences concerning access to needed resources.

The time factor was identified as a barrier to learning, though the way in which time hampered learning varied. Each teacher does have a scheduled planning period within their day, when obligations such as planning, scoring of assessments, preparation of materials, and collaboration with teachers or administrators may take place. Jordan explained how time was "limited during the school day and I am not always able to prepare hands-on activities for all of my classes." Within this constraint Jordan made alternative instructional choices. Helen reiterated that the "lack of prep time was an issue" as was the "lack of time for learning about new NGSS concepts." Gina provided insight into the potential negative impact of this barrier by asserting "teachers were resistant to the extra demands on their time and money at their own personal expense." Jordan echoed this sentiment when he commented that many "colleagues resent having to spend their own money on supplies for science."

Content knowledge and pedagogical content knowledge. All the participating teachers identified unmet needs as a barrier to their learning. One such need that all teachers acknowledged was the need for additional professional development to enhance their content knowledge as well as give them strategies to enable them to facilitate bringing this new understanding into the classroom, which is termed pedagogical content knowledge. In response to the question about the support to respond to the NGSS, Helen remarked "I don't feel that there's any." Gina suggested that "having an elementary science supervisor with elementary experience would be good. There is a big disconnect with the experience of working with young learners." Gina's remark reflects the connection between development of content knowledge and pedagogical content knowledge and resources for deepening understanding in these areas.

When asked what was lacking in their teaching, teachers identified workshops or experiences that would enhance their understanding so that they could be better prepared. Ann and Fran each indicated they needed training on content and how to facilitate so that they could do a better job in the classroom. As Fran commented "I think my mind is prepared but I think that I'm going to now have to gain some more knowledge on different things to do." Supports identified by teachers as needed included more university led workshops that provided concrete examples and strategies for implementation. The lack of these supports was identified as a barrier to learning and growth. Development of skills to promote reflection and sensemaking were categorized by teachers such as Fran and Danielle as the means by which they would like to improve their teaching, though these skills would support their own learning process as well. Fran observed "I wish I was better at having kids write out their reflections, but I wasn't sure how to assess it." Danielle specifically noted that she needed support to "know more about how to get the kids to think critically so that the deeper level questions come up. There's inferencing involved and I think that they have trouble with that and maybe writing, writing to answer scientific questions." Increasing content knowledge of specific topics as well an understanding of how science differs from other subjects emerged as a clear need and a barrier that must be overcome for successful implementation of the NGSS. Fran noted that this understanding could develop with hands-on experiences.

"When there are demonstrations it helps me because I am not just locked into what was presented." Teachers acknowledged that support at the administrator level is necessary to address these challenges and promote the changes required within the district.

A second research question focused on examining the perceptions of barriers by administrators in regard to implementing the NGSS. Considering that administrators are the building leaders, they have a unique perspective of the building and district demands that must be navigated.

Research Question 2

RQ 2: What do administrators believe are the barriers and challenges to implementation of mandated NGSS? Capturing the perspectives of the administrators revealed the challenges that come from within the building and must be negotiated in the context of district goals and state mandates. Themes of *tim*e and *material* concerns, competing *priorities* and the *limited role of the administrator* emerged as the noteworthy aspects that potentially narrow teacher learning and the effective implementation of the NGSS at both the individual teacher level and ultimately the district level. What administrators did/did not discuss also revealed their level of understanding and engagement with the NGSS. A lack of understanding of the shifts and expectations associated with the NGSS was apparent in the administrator level and may have possibly contributed to limitations on teacher learning and effective implementation.

The administrators interviewed believed their teachers were prepared to implement the NGSS. The confidence in the staff was high and the administrators did not express deep concerns about the ability of the teachers to deliver effective instruction in response to the changes within the NGSS. The administrators themselves could not elaborate on any details of what the NGSS represented in regard to changes in instruction.

The administrators in the study also related that professional responsibility was high within the district and guided the efforts of teachers to be prepared. Sam elaborated on this idea with the explanation that “many of our teachers are from this town, they care deeply about these students, and they work hard to be prepared.” Administrators promoted teacher growth in multiple ways including supporting attendance at workshops and the scheduling of a common prep period as formal mechanisms to support teacher collaboration. Administrator Pat was explicit in the intention of this scheduling to support professional learning, though it is not available in every building if only one teacher is assigned to teach science at a particular grade level.

Professional learning communities. Documentation of PLC activity is reported to building administrators through an attendance log or as Pat showed, from an activity sheet with a one sentence description of the discussed topics. Administrators Lynn, Max, and Pat all identified PLC sessions as an opportunity for professional learning and that in this framework, this is how teachers learn and get new information. Pat elaborated that “an underlying goal of the PLC structure is to bring veteran and new teachers for mentoring together to collaborate,” though that is not formally considered in designing the PLC members. Pat further expressed hope for the PLC interactions: “You get to pick each other’s brain. We have a lot of young teachers, so it’s important for them to be able to pick the brains of the veteran teachers. It works out.” Lynn identified the mentor relationship between novice and veteran teachers as “an effective strategy to support growth.” Sam and Pat are administrators who identified “leader teachers” as important mentors. Leader teachers were defined differently by each administrator; one indicated they had high evaluation scores while the other administrator said lead teachers have high student test scores. The mentor label was inconsistently applied throughout the district. Sam noted that “the district has developed some lead teachers who have had excellent evaluation scores over the past few years. They have been leading (no pun intended)--meeting with groups when we write curriculum.”

Max focused on the minimal role of the administrator during PLC meetings, “to be supportive but not take on a leadership role.” Max circulates among PLC groups to keep current on PLC topics, but does not dictate what the topics should be within the PLC group. Sam advocated for teacher led PLC meetings because based on his experience, teachers will “learn best when their colleagues give presentations. Why? Because they are more realistic and are valued more than outside professional development.” Sam commented that his own experience with professional development was not positive when he as a teacher felt “colleagues had increased credibility and increased engagement of coworkers because the presenting teachers give real examples.” Lynn described positive PLC interactions from last year in which her role was supportive. “Last year I decided once a month I was going to meet with their grade level PLC and that was probably one of the best decisions because it’s just an opportunity for them to say here’s what not working and how can you help us.” Administrators also support teacher attendance at district grade level meetings as a formal approach to facilitating teacher growth.

Building administrators agree that attending the university workshops and additional programs offered through the university have been beneficial for the teachers. Max, Lynn, Pat, and Sam highlighted that they support teacher participation at additional university level workshops, as Max explained, by “approving teacher attendance at the district level through formal requests.” Pat indicated he is able to “support requests by signing them and sending them to central office. 90% of the time they always approve it and they are on board unless the cost is outrageous or it there’s something that’s a deterrent.” Taylor described the feedback from teachers who attend university programs as excellent. “Teachers love it. They know they can do the activities in their classroom after the fact which is good, so they’re taking something out of it which they like.” Pat recognized that learning from the higher education professional development experience should be incorporated into peer learning opportunities. Pat and Sam were explicit that within their building there is an expectation that teachers who attend additional professional development workshops will “turn-key” the knowledge. This turn-key training could occur during PLC or grade level meetings. Sam described one such example

> After my faculty meeting yesterday two of my teachers in the NJRAISE program (university led program for multiple districts to integrate NGSS) spoke with other teachers in the PLC, the information that they’re getting from those types of workshops and groups, and just sharing it in the building. I know a few of my

> teachers have given presentations that their colleagues have benefitted from because again, it's realistic. They are getting information that they're using in their own classrooms, and it relates to their colleagues and what they can do in their own classroom.

Time. Administrators had to fulfill an increasing number of state required mandated trainings required for the teachers by scheduling these sessions during faculty meetings and professional development days. The mandates were explicitly described by three of the five administrators, as Lynn explained. "Once a month they (teachers) would get district training. Even on the heels of that, the state mandates that come down, you have to do HIB and blood borne pathogens training and all the district requirements." Pat described that his teachers were required to attend "dyslexia updates." These trainings limited the time available for learning in science or other disciplines. To balance fulfillment of state mandates and create a space for professional learning, the district relied on the PLC model to promote peer learning and growth. While all administrators conveyed, that teachers could use more time for professional learning, one administrator, Taylor noted that the "district expectation is that teachers will work on learning on their own."

Materials. Administrators identified an anticipated lack of materials as a possible barrier to implementation of the NGSS. While all participant teachers already bought their own supplies for the classroom, they noted a lack of materials as a critical barrier to learning. The administrators were aware of the shortfall and speculated that it will *become* an issue. The administrators again indicated that state mandates have increased expectations such as those in the new NGSS, but the funding to support the implementation for these mandates has not increased. There was no anticipation of an increase to their budgets for additional materials and the administrators were unsure of the scope of material support that would be needed to reflect the active nature of the NGSS. When probed about budgetary constraints Max explained, “ I can get funds from petty cash, but for other items we do need to do a purchase order and yeah, then I do approve that, but as long as it’s school related, and we can justify it, then that’s not an issue.” In contrast Lynn did not feel there was as much flexibility. “We do get a budget. 95% is on textbooks and workbooks and essential items.” Lynn explained the increased role of technology to support student learning as a driver to limit consumable supplies. Lynn remarked “I have gotten really far away from consumables because from grades 2-8 they have chrome books. I told them this was the last year I would do any consumables because they can take their chrome book home and there’s most material online so they can do it that way.” Pat echoed similar concerns with budgetary constraints. Pat commented that “funding is always an issue. We would love to buy all these great props and learning manipulatives and all these technological and all these programs. Unfortunately, we can’t afford everything we could like to.”

Several administrators said they were not asked for supplies by their teachers, and when probed further, Sam provided a representative answer speculating “that perhaps teachers were hesitant to ask because they were scared or do not want to appear as a burden, especially if they are non-tenured.” All of the administrators did remark that they did not proactively seek out feedback on material needs from teachers and did not want to openly advertise that there were funds available. Whether the building or district level was responsible to provide this support was unclear to both teachers and administrators.

Role of administrator. The role of the administrator in defining the duties and responsibilities as an instructional leader within their schools was not made clear by the district and created significant barriers in the support of teacher growth. District level administrators at the central office have not effectively disseminated information related to the NGSS to building level principals and this contributed to a disconnect that had a negative impact upon professional development planning and evaluation. Monthly focus meetings between central personnel and building principals provided opportunities for updates including mandates, timelines, and curriculum. These meetings addressed all district activity and did not specifically focus on science for a significant amount of time. Lynn's experience can be captured in her description, "We get that (information) from the central office. There's a director of math and director of science so they kind of tell us and I don't really know them." Lynn further explained, "the standards themselves come from our director in schools. They come down to us so that's how we kind of learn that." Pat recalled a similar pathway of dissemination.

> I go to two meetings. I go to the principal meeting and the focus meeting. At that point the central office staff will lead the meeting and they'll pretty much give us the updates on what's coming down the road and which directions we're going, and if it affects one particular subject area, that director can take the lead and fill everyone in. They'll (directors) send it directly to their teachers and they'll usually CC us on it.

Of significance is Pat's summary, "Some things come down from the building level, administration, something comes down form the curriculum directors, and sometimes the two meet in the middle, but sometimes it's two different highways."

As Max remarked, "In the beginning of the year, that's when we first started hearing about the new standards coming into place. We heard it through our orientation meeting when we came back in the end of August, but it's really the responsibility on the director." Max elaborated,

> it's really the responsibility of the directors to inform the teachers of how to utilize them and incorporate them in conjunction with the common core standards so that's what I would state is that it really falls in the director's lap to be the expert in that area to tell the teachers what to expect and how they are going to incorporate them into the curriculum.

Principals asserted that the science supervisor was responsible for managing teacher learning and identifying teachers in need of additional support. In contrast to this thinking, the district science supervisor remarked that "principals were present in each building and they were the ones who will know if the curriculum was being implemented, identify needs of teachers and facilitate support." The district science supervisor was not a direct supervisor of kindergarten through third grade and this further distanced the early childhood grades from the goals of NGSS for teachers of lower elementary grades. There were no formal mechanisms to facilitate collaboration between the early childhood director and the science director. The science director was able to communicate easily with the math director. As noted "we divide up the professional development days between us to meet with the teachers." Therefore, the formal opportunities that exist on the school calendar for professional learning are divided amongst the major subject areas.

At the time of the interviews for this study administrator training on the NGSS was minimal and therefore administrator familiarity of the changes associated with the shifts in NGSS was not at a level needed to support and facilitate learning and change. When probed to describe the changes to the science standards within the district the administrators serving as principals were unable to articulate what any of the changes actually were; the administrators were not sure of what topics were presented in each grade or how the NGSS differed from prior standards. The administrators were aware that engineering was now required as a part of science instruction but were not able to elaborate on what that would look like in the classroom. Four of the five participating administrators indicated that they relied on monthly focus meetings with the central office to keep them up to date on curriculum reforms and that science was not a priority at these meetings to date.

Priorities. Administrators, in agreement with teacher perceptions, identified competing priorities as a barrier to growth in science learning for instructors. Language arts and mathematics remain a district priority due to state mandates tied to funding. District performance is in part measured by the yearly student performance in language arts and mathematics assessments. Sam exemplified this focus when he stated "obviously language arts and math have been the focus statewide. I guess, nationally." Sam further elaborated that with the new science standards "you can see there's more of a focus that we're trying to get the science curriculum. I don't want to say at the same level as the language arts and math because I think that's always going to be the top priority." Science gains are however evaluated only once during the elementary school year. This priority on language arts and mathematics is also confounded by requirements to use student data as part of teacher evaluations. Administrator responses to priorities also reflected their personal backgrounds and building needs. As Max exemplified this point by stating, "my background is special education, so when it comes to modifying the in-class support situation, I'll be happy to help and give my suggestions based on my experience." Two of the administrators had significant special needs populations at their buildings and this circumstance creates additional demands on time and resources within the building. Administrators also acknowledged sometimes competing priorities that are revealed during dissemination efforts. As Pat described in relation to the rollout process "Some things come down from the building level, administration, something comes down form the curriculum directors, and sometimes the two meet in the middle, but sometimes its two different highways."

Professional development planning reflects the district priorities. Two administrators, Pat and Sam remarked that the agenda for professional development time within each building was set at the central office level and that they had little influence on the direction or timing of these sessions. Administrators at the principal level served as the conduits for information transfer between central office and staff at the building level.

Summary

In this chapter I presented the results of the study. To create context, I described the setting, the demographics and strategies used in data collection. I highlighted significant comments from participants and summaries from my researcher log to illustrate how participant experiences were valued and processed. I then explained the analysis approach that I utilized and represented the results as they related to each of the research questions.

The first research question addressed through the interviews examined how elementary teachers perceived their needs for learning new science and engineering content knowledge and acquiring pedagogical content knowledge for teaching in response to NGSS reforms. Teachers did not focus on their own lack of knowledge but on the available supports to address acknowledged needs to increase content and pedagogical content understanding. The results were presented in terms of the themes of *motivation* and *preparedness*. The participating teachers recognized that changes advocated within the NGSS represent change for them. These changes are creating motivation to increase science or engineering content understanding and increase skills to enhance their classroom practice. The goal of being prepared for these changes in the classroom resonated as a common theme amongst the teachers. The desire to provide hands-on learning experiences for students and the ability to answer student questions emerged as top motivations driving continued learning for the teachers. Teachers wanted to be prepared and be effective in the classroom.

While all the participants identified being motivated to learn new science or engineering as a need to support preparations for the changes associated with the NGSS, there was a range to how well the participants described their level of preparedness as the new school year started. There were variations in levels of understanding of the NGSS and this corresponds to the descriptions the participants gave of their being motivated as well as prepared. The variations also relate to the types of changes needed to adequately implement the NGSS. All of the participating teachers related that hands-on activities were the most beneficial to being prepared and effective. Their understanding of the content and of pedagogical strategies appeared to be a direct consequence of the ability to facilitate hands-on activities with students. Participants articulated solutions in a range of strategies and supports that were necessary to meet the increased demands of science and engineering understanding associated with the NGSS.

The first subquestion further probed examples of these strategies and supports designed to enhance teacher learning. Formal and informal supports were identified by both teachers and administrators. Informal interactions such as the internet and collaborations were effective at the building level and enabled different degrees of learning for instructors. Formal structures, including building level PLC sessions, district wide grade level meetings, and additional university provided workshops, were acknowledged as essential supports to enhance both content and pedagogical content knowledge for elementary teachers. The participating teachers all commented on the potential of these various mechanisms, and have experienced mixed levels of success utilizing the supports. During the interviews teachers also identified formal barriers ranging from building and district meetings and curriculum as well as including remaining needs which hindered their learning of new content associated with the NGSS. These barriers were explained under the following subquestion.

The second subquestion in the study probed teacher perceptions of barriers and challenges that hamper their ongoing learning in connection to the NGSS. Formal and informal mechanisms were described, many of which were also characterized as potential supports to learning. PLCs, grade level meetings, district curriculum, and priorities all created additional demands on teachers' time and attention. The lack of material resources and time to prepare adequately emerged as strong contributors to the barriers which blunt teacher growth in relation to the NGSS. Individual building culture and management may also be contributing factors as the administrators' mixed organizational perceptions had impacts upon short and long term goals and growth for teachers. The need to further develop content knowledge and pedagogical content knowledge in science as part of future teacher professional learning was impeded by an administration uneven in its role in response to the required mandate. The administrators' own perceptions of barriers were also explored in order to identify contributing factors to the challenges of ongoing professional learning.

The second research question concentrated on the perceptions of administrators related to the challenges of implementing the NGSS. Administrator understanding of what these changes constituted, and what supports were required to adjust to the reforms was lacking and contributed to issues concerning the provision of appropriate support. The role of the administrator in promoting professional learning lacked uniformity between buildings and is not developed from the central office level. Administrators understood that time and materials were limited and that pressure to meet preexisting state level mandates created priorities that conflicted with growth in the areas of science and engineering.

Changes in expectations are creating disruptive events in the classroom. Teachers, in response, are anticipating new content and pedagogical content strategies needed to effectively implement the NGSS and are thereby experiencing ongoing learning. Supports and barriers exist at the building and district levels that can be characterized as both formal and informal in nature. Chapter 5 will take the findings through an analytical discussion which expands the understanding of the results and illustrates connections to the conceptual framework, situating the results within teacher education presented in the literature review, and highlights opportunities for social change. Areas of potential research designed to explore the strengthening of professional growth and the development of improved instruction within the arena of science and engineering will also be discussed.

Chapter 5: Discussion, Conclusions, and Recommendations

Shifts within the NGSS require enhancements to the content knowledge that elementary teachers possess in order to effectively implement science and engineering instructional strategies within the classroom. The process of how in-service elementary teachers approach learning new concepts in science and engineering is not well understood nor prominently represented within the literature. The purpose of this interview study was to explore the perceptions that teachers and administrators had of the supports and barriers to continuous professional learning of science and engineering in response to the reforms of the NGSS.

The conceptual framework of this study was shaped by Schön's (1983, 1987) theory of reflective learning and Weick's (1995) application of reflective learning as sensemaking. These theories allowed for the exploration of why and how adult learners approach the understanding of new content. I found that in-service elementary teachers were inspired to learn through motivation to understand the NGSS and to apply this understanding to be prepared to use the NGSS in the classroom. Teachers used both informal and formal strategies, including the internet, informal collaborations, PLCs, grade level meetings, and professional development opportunities from higher education. They also used these strategies to support their professional learning and to overcome barriers to this endeavor. Barriers identified by teachers that limit learning included the facilitation of formal structures such as PLCs and grade level meetings but also included constraints arising from curriculum and assessments, time, and priorities within the district. Administrator perceptions of the barriers that arose from time and materials constraints as well as from their own potential obstruction demonstrated some overlap with teachers' perceptions and revealed how school culture had an impact upon learning opportunities.

In this chapter, I summarize and interpret key outcomes of the study and acknowledge the limitations of this inquiry. Additionally, I offer recommendations for further research on teacher learning of science and engineering and identify potential implications for social change as a consequence of this learning.

Interpretation of the Findings

In this interview study, I explored teacher perceptions of the supports and barriers that aid or hinder professional learning of new science and engineering content in response to the NGSS reforms. I also explored administrator perceptions of professional learning needs for elementary teachers of science and engineering to examine viewpoints from a building or district perspective. Of significance was the lack of understanding of what changes in content and pedagogy are required to transition to the NGSS. The lack of understanding of science and engineering content was demonstrated by the minimal detail of the concepts described by both teachers and administrators. The results demonstrated that a complex approach to professional learning included both informal and formal mechanisms and that structures in place acted at times as both supports to professional learning and as barriers to overcome. Dominant themes of motivation and preparedness emerged as the driving forces stimulating continuous learning of science and engineering concepts. Elementary teachers wanted to be prepared and effective in the classroom, and this required the ability to facilitate hands-on experiences with their students and engage in meaningful discussions with them about how the world works. Teachers and administrators recognized that teachers needed time and varied support mechanisms to achieve these goals.

Alignment to the Literature

The findings of this investigation aligned with current research in related areas of teacher learning. Recently, the NRC (2015) called for multiyear professional development plans to support the transition to the NGSS, understanding that the expectations of content knowledge and pedagogical content knowledge are beyond the formal training of many teachers. As noted by Liu et al. (2012) and the NRC (2010), teacher backgrounds were limited in relation to science or engineering understanding. All of the participating teachers indicated they required additional support to enhance their content knowledge and pedagogical content knowledge. In contrast to the findings of Wilson-Lopez and Gregory (2015), the teachers in this study did not report feeling uncomfortable teaching science or engineering, though they did correspondingly acknowledge a lack of content knowledge and pedagogical content knowledge in both science and engineering as areas to enhance in order to be better prepared for the classroom. The teacher perceptions of their knowledge levels were surprising. The majority of teachers could not articulate what topics would be required at their grade level in response to the NGSS, yet teachers did not express concern over this lack of understanding. Their priorities focused on external supports to close this gap as related to being prepared for the classroom.

Teachers identified the informal strategies that supported learning as helpful at both an individual and group level. The dominance of the internet as a top resource emerged, though vetting the information for accuracy was not consistently strategic amongst elementary teachers. Teachers struggled to clarify how they determined if lessons were aligned to NGSS or appropriate for their classroom, demonstrating their lack of content knowledge or of strategies to translate the information into the classroom. The ability to assess the quality of resources appeared to be lacking. This insight highlighted the challenge concerning the ability to discern the efficacy of resources. An awareness of this deficit by many of the teachers drove the motivation to learn within this group and supported the prior findings of Brown et al. (2011). These results showed that online resources may play a large role in supporting future learning within the field for the teachers.

Informal collaborations during the school day had the potential to be effective at promoting learning through discussions in with grade level peers or other colleagues in the building or district. Teachers described the reliance on conversations with colleagues to support learning, and a few, specifically Ann and Betty, articulated the importance of email between colleagues to share questions and resources. These informal approaches exemplified teacher strategies to learn new material through informal conduits that exist within the school setting and were influenced by how well teachers “got along” with colleagues. It was apparent that social relationships in the work place had an impact upon the experience of the personnel. Teachers who were socially isolated without peer interaction may have been professionally isolated as well and limited in opportunities to learn mandated content and strategies through informal avenues.

Formal structures within the district created the potential for continuous learning at both the building and district levels. Common planning time and mentoring programs emerged as identified formal support structures, though the effectiveness varied based on the individual experience at the building level. Only one teacher noted a personal benefit from either common planning periods or mentoring relationships, though all the teachers identified common planning as a potential source of learning. Teachers were able to distinguish between what their personal experience was and what may have been the experience of other teachers based on the opportunities that exist within the building and district. This ability to distinguish between self and the larger community of teachers reinforced the identification of varied supports, even if many of the teachers did not personally benefit from them to date.

PLCs existed within each building and were the formal learning mechanisms used by the district to promote growth within each building. Grade level meetings at the district level brought together teachers within a similar grade band and were also identified as potential opportunities for individual teacher growth, in agreement with several studies (DuFour & Fullan, 2013; National Academies, 2015). The reality of facilitation though led teachers to comment that these supports rarely led to their actual increased understanding of science or engineering. Reimer et al. (2015) also noted the challenge for facilitation of professional support as related to time as a challenge for leadership. Administrators echoed similar concerns in this area. Teachers commented that highly effective grade level meetings were ones in which local university personnel provided professional development related to hands-on concrete examples of performance expectations of the NGSS. Similar to the findings of Bissaker (2014) and Handa (2013), describing the development of content knowledge and pedagogical content knowledge, teachers in this study identified learning as occurring through interaction with higher education professionals.

In contrast to these supports for professional learning, barriers existed that appeared to limit teacher growth. Many themes, such as PLCs and grade level meetings, were categorized as supports by the teachers and were also identified as barriers. PLCs and grade level meetings were described by teachers as not supportive in reality and priorities of other curricula, and required assessments at the district level were characterized as negatively influencing teacher professional learning. District priorities that conflict with science and engineering goals along with a lack of resources and contradictory curricula also emerged as obstacles to professional learning for elementary teachers. Fran and Helen both remarked that during faculty meetings, science never came up as part of the agenda. Danielle echoed a similar experience, sharing that time spent within PLC meetings or faculty meetings was not focused on learning but on providing logistical updates to the faculty. An inference drawn from the participant teachers' remarks would imply that science was not a priority within their district.

Gina provided insight into the potential negative impact of time and material constraints as a barrier. One pointed issue identified as a barrier emerged. This was the assertion that teachers were resistant to the extra demands on their time and money at their own personal expense. A significant outcome was that the teachers needed guidance to use their meager existing resources to best implement the changes mandated for the learning of new science concepts.

Administrator perspectives also revealed incompatible district level priorities as an obstacle as well as a lack of time and resources availability. Teacher statements agreed with these incompatible demands placed upon them. Teachers noted that they were required to give benchmark assessments that were aligned to the one common resource, a workbook, with a scope and sequence that was outdated. An additional priority was that these assessments had an impact upon teacher performance evaluation scores. This effect of disconnected curriculum goals and pacing guide conflicted with NGSS changes, leaving little room for teachers to try out new concepts. The culture within each building and its management contributed to mixed organizational perceptions that have influenced short and long terms plans to support teacher learning.

The resulting effects of these mechanisms, either as supports or barriers, influenced the professional learning of elementary teachers of new science and engineering content that was expected to translate into classroom practice in response to NGSS reform. These findings aligned with the work by Brown et al. (2011), who noted that both teachers and administrators needed an increased awareness and understanding of science and engineering to promote effective integration. A lack of understanding of the shifts and expectations associated with the NGSS was apparent in the administrator level and may have possibly contributed to the limitations on teacher learning and effective implementation.

Findings Related to Conceptual Framework

Looking through the lens of adult learning theory as described by Schön (1983) and Weick (1995), participant statements revealed their motivations and approaches to learning. The changes advocated within the NGSS represent a disruptive event as that defined by Schön, and teachers had an increased awareness of their want of understanding of science and engineering concepts. The teachers' own cognizance that there was a need for further development in these areas provided motivation for learning new concepts.

Participant statements provided several examples of how the motivation to absorb new concepts was situated within the reflective learning framework. Changing standards prompted learning to enable increased classroom effectiveness and enhance preparedness. Ann noted that reflection was often needed after class in order to put the experiences (of what happened during class) into the context of the children's lessons. This statement was reminiscent of Schön's (1983) reflection on action adult learning. Responding to these new demands within the classroom setting suggested Schön's notion of a disruptive event to precipitate learning and extended to Weick's (1995) concepts of sensemaking. This dynamic put new learning into the existing framework of classroom science instruction. Teachers were working towards being better prepared for their own classroom instruction.

Descriptions of not being prepared for the changes most likely reflect the level of understanding of the NGSS and of the changes needed to adequately implement the advocated concepts. Of note was that many teachers described that their motivation for learning was linked to being prepared for the classroom and that this preparedness was in turn tied to facilitating the hands-on activities in the lesson. Understanding of content and of pedagogical strategies appears to have been directly related to the ability to facilitate hands-on activities with students. Chris, for example, connected the concrete examples as critical to identify what should be used in class, which exemplify Weick's (1995) notion of sensemaking within the group setting of the classroom.

The framework of Schön's (1983) reflective learning and Weick's (1995) sensemaking emerged in teacher descriptions of formal professional learning experiences. Teachers reflected on the support of the higher education workshop experiences and described elements of sensemaking to apply learning within the classroom and personal understanding developed through hands-on experiences. Ann elaborated on the hands-on aspect of the workshops. It was important for her own understanding, and she felt this hands-on activity approach would work for the children. Ann articulated that she took the ideas from the workshops right into her classroom. The teacher remarks of employing the new knowledge to enhance classroom practice aligned with Schön's ideas that the disruptive event prompts new learning.

As Fran described her experience, the workshops were "not just transmission of set facts but there are discussions and questions that get you to think about how to use the information." The positive teacher feedback associated with the university led workshops signified the value that the teachers placed on these experiences. These comments of translating workshop understanding into the classroom echo the sentiments of Weick's

(1995) sensemaking ideas of incorporating a new understanding into the structure of the classroom.

Professional development experiences such as the university led workshops were expected to be incorporated into peer learning opportunities by administrators. As administrators, Pat and Sam were explicit that within their respective buildings, there was an expectation that teachers who attended additional professional development workshops would “turn-key” the knowledge to colleagues. This strategy implied that knowledge gained from a workshop experience would be disseminated to teachers who were not able to attend the workshop. Administrators supported this approach by carving out time during three building professional development days in a formal way to facilitate these collaborations. Teachers, however, did not report that any professional learning occurred through this approach and, therefore, left its impact as a powerful or effective tool in question.

Limitations of the study

As stated in Chapter 1, this study was limited to the features of one urban school district and the characteristics of the voluntary participants who were recruited through purposeful sampling. The eight elementary teachers were tasked to respond to changes in expectations in response to transformations associated with the NGSS. The five district administrators who participated responded with statements that reflected the multifaceted responsibilities of their leadership positions. The implementation timeline of responding to the NGSS may have been a limitation in the study. The expectations of the implementation may have created bias from the respondents even though the semi structured nature of interview protocol served was designed to minimize any potential bias.

Researcher bias also is a limitation within any researcher study. The use of controls mentioned in Chapter 3 diminished this prejudice. The reliance on the literature to inform the development of interview questions, initial coding and the use of open coding in subsequent analysis, minimized researcher bias as did a protocol for recruitment and data collection.

Therefore, the generalizability of the study's findings was limited to the district from which the sample came, and only in the broadest sense can be applied to other districts if variable such as characteristics and formal structures to support learning are present.

Recommendations

The strengths and limitations of this interview study provided insight into future opportunities for research in this area of teacher learning. Researchers furthering this line of research might explore studies related to perceptions of teacher learning needs for science and engineering. Studies that further identify teacher levels of understanding of science or engineering concepts are needed to develop programs which address the gaps in knowledge between teacher comprehension and the proficiency needed for the classroom. Any future review of teacher preparation programs should consider these findings as they indicate that teacher preparation programs are insufficient for preparing elementary teachers to be classroom ready in regard to science and engineering. This study was limited to urban in-service elementary teachers. The perceptions of learning needs by elementary teachers in rural or suburban areas could be explored utilizing the same interview protocol and data analysis strategies. Examination of findings in various settings could identify patterns of needs of elementary teachers to inform professional learning through professional development planning across varied school settings.

A unique finding which emerged in the study was the theme of the teachers utilizing internet searching for their own learning. The pervasive use of the internet and online resources was identified by all teachers as the initial step taken to examine new science and engineering topics and to understand the concepts. However, teachers were unable to describe effective strategies to identify resources which were accurate or appropriate to their needs. Future research could explore the process of how online resources are vetted as reliable ones. Research should be designed to examine the features of web sites that teachers identify as helpful and which align with NGSS content matter. Understanding how teachers utilize online resources may inform web development of more appropriate resources to aid individual teachers who are learning on their own, Of interest may also be how helpful online sources are at providing hands on example information and the exploration of how these resources are used in the classroom could be of interest in future research.

The question of the effectiveness of learning strategies utilized to develop understanding of science and engineering should be raised in future studies. Quantitative studies could also be developed to analyze what content knowledge is gained by participating teachers. Studies could be designed to examine the changes in understanding of content knowledge within each of the science domains or within engineering after the identified learning supports are implemented, whether these supports be university-led professional development, PLCs, grade level meetings, or individual learning.

The facilitation of professional development by university led individuals was identified by all the participant teachers as effective and supportive of personal learning. The differences between these university sessions and district led ones such as PLCs or grade level meetings could also be explored to identify critical components of science and engineering integration or alternatively, to explore components of effective professional development. The strategy of professional development delivery, therefore, could be further examined to identify elements which may support teacher development.

A quantitative approach to university led professional development would provide additional insight into the impact upon learning through this avenue. Content level assessments administered in a pre and post manner could frame an analysis that evaluates the learning gains from the hands on workshops led by university staff that teachers identified as supportive of their learning. Teacher attitudes in relation to confidence and competence could also be measured using quantitative instruments. The role of administrators to support teacher learning should also be further explored. The perceptions of both teachers and administrators would be further examined to better understand the roles of the building administrators and the avenues that exist for them to better support professional learning among the faculty.

These further studies in the areas mentioned above could add to the field of teacher learning and specifically to support efforts to understand factors that influence the professional learning of elementary teachers. Studies may range from examining changes in content understanding in science or engineering to examination of classroom facilitation research. Opportunities for additional research exist at both qualitative and quantitative points. The identification of effective professional development features could also be an outcome of some of the studies described above.

Implications

This research contributed to the Walden University's mission for positive social change by providing a deeper understanding of teacher perceptions of learning to inform inservice learning opportunities at the elementary level. Supporting teachers at all levels of instruction is essential to facilitate movement along the progression of student learning in each subject area. Elementary teacher content knowledge in science and engineering is recognized as weak as compared to preparedness in other subject areas (NRC, 2010). Teachers in this study followed this pattern and were not able to articulate the science and engineering concepts that they will be expected to facilitate in the classroom. Elementary teachers are expected to enhance their own content and pedagogical content understanding as needed in response to changing standards and expectations. Teacher experiences with professional learning opportunities affect their perceptions of the effectiveness of these mechanisms. Teachers have varied levels of success with formal and informal mechanisms that exist to support professional learning.

While previous research focused on supporting secondary teachers who are developing understanding of new material, through this study I provided insight into how to better support the growth of elementary teachers who must implement new science and engineering content. Research by the NRC (2010) determined the formal training of elementary teachers in the areas of science and engineering is not adequate. All elementary teachers are now required to address the significant changes associated with the NGSS (NGSS Lead States, 2013). Fostering a stronger foundation of science content knowledge and pedagogical content knowledge for practicing teachers at the elementary level is necessary and therefore critical to effective programs that support student achievement. Consequently, there was a need for increased understanding of what teachers and administrators believe is needed for them to increase understanding of content and pedagogical content knowledge within science and engineering concepts at the elementary level to meet the demands of the NGSS. The planning of professional development for inservice teachers can be enhanced with the integration of strategies identified by teachers within this study to support learning.

Strategic use of methods such as the use of online sources can be explored through professional development sessions and can capitalize on teachers' interest and reliance on the internet. A suggested addition is the creation and exploration of reliably sourced internet sites for information sharing by the administration. This could include the vetting of resources, or the provision of recommended sources, to help teachers to explore and differentiate between sites with evidence based research examples and those without. The district science supervisor has the background to effectively implement this suggestion.

Enhanced use of other strategies identified within the study as supports for learning could advance positive social change by advancing teacher learning as well.

Support for formal structures such as a priority focus for science and engineering at PLCs and grade level meetings could facilitate engagement with active learning models such as hands on examples and the discussion of translating these into classroom practice. Teachers have identified these strategies as essential to promote their own learning. Enhanced professional learning and support of elementary teachers can, also, lead to an increase in the expertise of teacher content and pedagogy content knowledge, with the goal of increasing efficacy and confidence in science and ultimately supporting student achievement.

Conclusion

Implementation of the NGSS will require development of content and pedagogical content knowledge for elementary teachers that reflect authentic practices and understanding of science and engineering concepts. Little was known about how inservice elementary teachers approach learning to meet this task. My work in this interview study explored teacher perceptions of strategies to support learning and barriers that hamper learning at the building and district levels. Administrators were also interviewed to identify their perceptions of barriers to elementary teacher learning, identifying possible areas of overlap.

Findings suggested that teachers used both informal and formal strategies to support their own learning. Capitalizing on the overall interest of online resources could promote teacher growth as well as the implementation of formal structures as intended including PLCs and grade level meetings. These formal supports may help mitigate the issues of barriers of time, materials and priorities that are recognized by both teachers and administrators. Teachers were motivated and eager to be well prepared for the changes associated with the NGSS. They wanted to learn new science and engineering concepts. Finally, the goal of the NGSS effort is to increase the knowledge and literacy of elementary school students in science and engineering. Investigating the implements by which our instructors are expected to carry out this mission and improving their tool box, is vital if we are to create positive societal change and compete in the technologically centered 21st Century.

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Appendix: Interview Prompts

Interview Protocol for Elementary Teachers

Introduction and review of the consent form.
Clarification that the interview will be recorded.

Background information
How long have you been teaching for?
During this current school year, how often do you teach science? For how long (describe the model time/days)
What topics are you covering this year?
What do you do to prepare for teaching about a topic?

1. What approaches do you take when you are teaching a topic that is new to you?
2. What kind of professional learning do you engage in to stay current and to improve your effectiveness in the classroom?
3. How would you describe what makes you become better at effectiveness?
4. What motivates YOU to learn science?
5. Describe any professional learning support at work.
    a. Who has been the source of any support you have received?
6. Have you been introduced to the Next Generation Science Standards yet? If so, when and how?
7. Tell me about the support that has been available in responding to the new Next Generation Science Standards?
8. What do you think will be the biggest change to your teaching based on what you do know about these standards?
    a. How would you describe your level of preparation for these changes?
    b. What type of experiences would best help you to get ready for these new standards?
9. How do you learn about new topics in areas that are not science?
    a. Can you give me an example?
    b. Do you think that approach would work with learning new science content?
10. How long does it takes to get comfortable with a new topic? What does comfortable "look like"?
11. Do you feel anything is lacking in your science teaching? If so, please discuss.

    If participant mentions standards/curriculum, ask them to clarify.
    If participant mentions topics probe to see what their experience is with science/engineering?

12. Have you ever taught engineering before? What would help you to understand engineering concepts so that you could present them to your students?

13. How does your building administration respond to learning needs in general?
14. We have addressed the questions I had, is there anything else you would like to add to our conversation?

Thank you again for your time and insight. It was a pleasure speaking with you today! Your insight can help me to better understand the issues surrounding professional development and continuous learning of science and engineering for classroom teachers. If you have any questions or comments later on, you have the contact information on the consent form for follow up.

Interview Protocol for Administrator

Introduction and review of the consent form.
Clarification that the interview will be recorded.
Background information

How long have you been an administrator/supervisor for?
What was your previous teaching experience?

1. How do standards reform initiatives or mandates inform or guide how teachers plan and prepare in regard to instruction?
2. How much flexibility do teachers have in their instructional planning to meet mandates? Is there emphasis on particular subjects?
3. In terms of how information is disseminated to individuals in leadership positions. When were you introduced to the Next Generation Science Standards?
4. Thinking about the science standards in particular, there is a 2016 implementation timeline for alignment for the MS and HS and the following year for K-5. What do you see as the needs to support the elementary teachers for becoming familiar and becoming comfortable to reach this target?
5. Elementary teachers are often literacy experts and do not have a lot of science coursework in their teacher preparation programs. It may be a challenge to support teachers who may not be comfortable with science but who are responsible for teaching it. How do you approach helping them to enhance their own understanding and ability to teach science effectively?
6. Do you feel your teachers have the content knowledge and teaching strategies to engage students with science or engineering concepts?
   If mentioned follow up with questions related to evidence of science or engineering in the plans books.
   If mentioned follow up with questions related to resources to engage students.
7. Do you think there are limitations on your ability to provide resources or professional development for your teachers?
   a. If participant responds yes, then ask them to describe.
8. We have addressed all the questions I had. Is anything else you would like to add?

Thank you for your time and insight. It is a challenging position that administrators are put in. Your insight can help me to better understand the issues around supporting continuing professional development of science and engineering for elementary teachers. It was a pleasure speaking with you today! If you have any questions or comments later on, you have the contact information on the consent form for follow up.