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Designing Three-Dimensional Implementation of NGSS to Support Science Education

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This is to certify that the doctoral study by

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Abstract

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MA, New Mexico State University, 2009

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Submitted in Partial Fulfillment

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Abstract

The Next Generation Science Standards transitions science instruction to a strategic focus on students' application of science content through sensemaking to deepen their understanding of naturally occurring phenomena. As an innovative educational initiative, NGSS requires a vast shift in how all stakeholders approach scientific learning in public education. New Mexico formally adopted NGSS in 2017 and promptly expected full implementation. The problem explored in this study is the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS, based on New Mexico's abridged timeline, inadequate funding, and limited professional learning. The study used a qualitative exploratory case study to explore three science education stakeholders' perceptions on the implementation of NGSS in four New Mexico school districts. The study was guided by sensemaking theory (Schön,1983; Weick,1995) as the theoretical framework. The *Framework* (National Research Council, 2012) guided the study's conceptual framework to analyze the perceptions experienced during NGSS implementation with three secondary principals, one instructional coordinator, and four science educators. Semi-structured interviews were analyzed through provisional and open coding. Results from the study indicate that experiencing the three dimensions of NGSS in professional learning is beneficial and sensemaking supports college and career readiness. The findings also suggest that the current instructional materials do not fully address NGSS and performance expectations are challenging to assess. Gathering data on NGSS implementation may provide guidance on the effort to transform science classrooms to meet globalized scientific literacy. Evaluation of implementation practices can strengthen effective instructional strategies evoking positive social change.

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Dedication

I dedicate this work to my husband and children. My husband, Ralph III, has provided me with consistent encouragement and love, which gave me the strength to embark on the journey of continuing my education. My three children, Legion, Nova, and Lucian, endlessly inspire me to demonstrate the outcomes of hard work and the value of learning. Thank you for being the most amazing children and making your mother proud every day. I am eternally grateful to my family for the encouragement, unconditional love, and support.

I dedicate this achievement to my parents, Mike and Terry Bloom, who have exemplified the value of education and whose sacrifices have provided me with the opportunity to pursue advanced learning. Without their continued reinforcement, this achievement would not be possible.

Last, I present this work in the loving memory of my mother-in-law, Mercedes, who was exceptionally proud of me for being the first member of my family to earn a doctorate. May her light continue to shine down on our family and provide my father-in-law, Ralph II, with perseverance.

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Chapter 1: Introduction to the Study

On November 14, 2017, the Next Generation Science Standards (hereafter referred to as NGSS; NGSS Lead States, 2013) was formally adopted by New Mexico (Workosky, 2017). Signifying the most substantial transformation in science education since the release of the National Science Education Standards (National Research Council, 1996), NGSS encompasses research-based expectations for K-12 students to meet the complexities of 21st-century learning (Bybee, 2014). Revising instructional practice, necessitated by the NGSS, can only be accomplished through an intentional and sustained effort, guided by professional learning and progress monitoring (California Department of Education Sacramento, 2018). The progressive achievement of adopting NGSS signified the need to reform science instruction in New Mexico to meet students' needs better. Immediately following the NGSS adoption announcement, the state's Public Education Department took swift action by mandating K-12 implementation by July 1, 2018 (New Mexico Public Education Department, 2018). However, the 7-month NGSS implementation timeline, inadequate funding to districts, and limited professional learning opportunities for all science educators has initiated concern that the current transition to NGSS may be insufficient to support of the process required for implementation in classrooms through the state (Legislative Education Study Committee, 2018a).

Constructed as a relevant and real-world set of science expectations, NGSS builds a deeper understanding of science concepts and integrates math and literacy (Marchesso, 2016). The implementation of NGSS can directly impact student achievement throughout the science, technology, engineering, and mathematics (STEM) pipeline, pre-kindergarten through postsecondary (Bybee, 2014). Challenges exist in integrating STEM due to teacher ability, time, lack of professional development, and funding constraints (Chalmers et al., 2017). A multi-directional structure comprised of content, occupational, and pedagogical knowledge increases STEM teachers' effectiveness (Yildirim, 2016). The technology component of STEM education encompasses a broad base of design, making, problem-solving, invention, and optimization originated through human technological innovation (Love et al., 2017).

Principals, instructional coordinators, and science educators have an essential responsibility in the instructional reform of NGSS. Yet, research indicates that they generally have a limited understanding of science practices and the three-dimensional learning necessitated by NGSS (McNeill et al., 2017). Quality academic standards, such as NGSS, help to set the expectations for all students and set the stage for post-K-12 education. However, they must be supported by sustained implementation practices to be effective (Achieve, 2019). Therefore, NGSS implementation should be considered foundational and matched with a sustained support structure to impact student learning in science successfully. This study explored NGSS implementation in New Mexico to determine the perceptions of principals, instructional coordinators, and science educators. Implications provided by the data collected may help determine the current coherence of NGSS-based instruction to provide insights on potential actions vital to increase student proficiency in science and strengthen the STEM pipeline.

Chapter 1 is organized to present the background, problem statement, and nature of the study. The related definitions, assumptions, scope, delimitations, and limitations are also included to support each section's relevancy to the context of the study. Finally, this chapter closes with the study's possible significance, including guidance on the investigations intended to influence positive social change.

Background

In 2013, the NGSS was released as a national research-based reform to science education. Derived explicitly from *The Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (hereafter referred to as the *Framework*; National Research Council, 2012), the NGSS encompasses a vision of science that asks students to engage in content by making sense of phenomena actively. "The *Framework* is based on a rich and growing body of research on teaching and learning in science, as well as on nearly two decades of efforts to define foundational knowledge and skills for K-12 science and engineering" (National Research Council, 2012, p. 2). According to The National Academy of Sciences, Engineering, and Medicine (2017), scientific literacy is the ability to comprehend how and why science and engineering are essential for society, distinguish how to reason from evidence, and make sense of the work that scientists and engineers do. Thus, as a central component of NGSS, scientific literacy contradicts the traditional format of rote memorization of science facts and instead expects a conceptual understanding of complex concepts.

In 2015, the Every Student Succeeds Act (ESSA) was signed into law. ESSA was a reauthorization of the 50-year-old Elementary and Secondary Education Act (ESEA) and replaced the No Child Left Behind Act. ESSA aims to improve teaching and learning by promoting equity for minority students, implementing evidence-based instruction, and providing specific guidance to increased STEM opportunities to improve college and career readiness (U.S. Department of Education, 2017). A dramatic increase in STEM-based jobs over the last 2 decades has led economists to determine that a STEM-proficient workforce will be one of the key drivers of the United States' future economic growth and development (National Academies of Sciences, Engineering, and Medicine, 2017a). Job-shadowing and internship programs for secondary students can increase student interest in STEM careers. However, the amount of time, money, and community support required often interferes with creating these programs (Mulkerrin et al., 2018).

Three-dimensional learning, as described in the *Framework* (National Research Council, 2012), designates student learning to integrate aspects from all three dimensions as they engage in the natural and engineered world around them while making sense of their observations (National Academies of Sciences, Engineering, and Medicine, 2019). Coherence in the teaching and learning cycle, aligned to the three dimensions of the NGSS, is a complex educational reform that will require a multi-faceted support system for teachers to implement in their classrooms proficiently. Unfortunately, independent state-guided adoption and local-control implementation of the NGSS has led to a wide variance in professional learning structures, rollout timelines, funding, and educator support in New Mexico. Except for California's K-8 early implementation study (Tyler et al., 2019), state implementation of NGSS has not been holistically captured and studied for application to other states. Furthermore, evidence provided by the Legislative

Education Study Committee (2017 & 2018a) and the New Mexico Math and Science Bureau (New Mexico Public Education Department, 2019) indicate a lack of research on the implementation practice applied to the New Mexico adoption of NGSS and ambiguous impact assessment of both funding and professional learning for science educators.

Therefore, a gap in research has led to a significant gap in understanding the practice of NGSS implementation in the state of New Mexico. As the other 19 states and the District of Columbia who have formally adopted NGSS each have vastly different timelines, funding, and implementation practices, using existing data provided does not directly correlate to New Mexico. Further exploration is required to determine the current methods used to implement NGSS in New Mexico and provide perceptions from the secondary education stakeholders responsible for implementing these transformative science standards.

Problem Statement

This study explored the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS, based on New Mexico's abridged implementation timeline, inadequate funding, and limited professional learning opportunities. After an arduous statewide political debate, on October 25, 2017, the New Mexico Public Education Department announced that the NGSS science standards would be adopted in their original format with an additional six state-based standards (Uytterbrouch & Burgress, 2017). Published shortly after the announcement of NGSS adoption, an implementation timeline mandated initial NGSS implementation effect on

July 1, 2018, with full statewide implementation in all grades (K – 12th) in August 2019, and an aligned state assessment by the spring of 2020 (New Mexico Public Education Department, 2018).

As a guide to both adoption and implementation of NGSS, Achieve (2013) released a workbook outlining the strategic processes and accountability structures required for an appropriate state transition to NGSS, which include NGSS-aligned instructional resources, sustained professional learning, and an extended implementation timeline. Contrasting New Mexico's 3-year NGSS implementation timeline, California employed a strategic 7-year timeline (California Department of Education, 2014), New York enacted in a progressive 5-year plan (New York Department of Education, 2018), and Arkansas embarked on a calculated 6-year sequence to full implementation (Arkansas Department of Education, 2014). According to the Legislative Education Study Committee (2018a), the aggressive timeline for transition to NGSS statewide was directed to all school districts with the potential of inadequate funding, instructional materials, or a consistent professional development model. The mandate of NGSS implementation in New Mexico was allocated to each district within the state to establish the specific process for enacting the shift of science instruction (New Mexico Public Education Department, 2018a). This district-driven implementation of NGSS may have created challenges for stakeholders in science education in the state of New Mexico and consequently prompts further investigation.

NGSS state-mandated policy should be supported through leveraging increased funding for implementation, capacity-building, monitoring, and classroom resources

(Achieve, 2013). According to the Math and Science Annual Report (New Mexico Public Education Department, 2019), New Mexico's Public Education Department provided direct professional learning support related to NGSS implementation to 422 science educators, educational leaders, and curriculum specialists during the 2017-2018 and 2018-2019 school years. Therefore, the number of science educational stakeholders receiving direct support for NGSS implementation during a critical time in the implementation process represents a significantly small proportion of science educators and educational leadership, based on the estimated total of 336,000 students in the state of New Mexico (The Nation's Report Card, 2019). In addition, during this same time period, in a landmark court case against the state of New Mexico, Yazzie and Martinez vs. State of NM, a judge declared that the state of New Mexico violated its constitution by insufficiently funded public education and failed to meet the needs of at-risk students in over an extended period of time (Legislative Education Study Committee, 2018b).

As specified by California NGSS early implementation administrators, sufficient time for teacher collaboration and professional learning was considered a significant barrier to the advancement of shifting to NGSS (Estrella et al., 2019). Notably, collaborative time for educators is generally caused by a deficiency in funds to support extra-hour agreements for participants. In designing and selecting an NGSS-aligned assessment, states should focus on coherence and consistency and prioritize meeting the objectives of three-dimensional learning over quick timelines (Achieve, 2018).

NGSS, published in 2013, was designed as a transformational set of educational standards, as an alignment companion to the *Framework* (National Research Council, 2012). Intending to provide equitable and conceptual-based learning for all K-12 students (Huff, 2016), NGSS strategically targets the transformation of science education. According to the National Science Teacher Association (2020), 20 states and the District of Columbia have formally adopted NGSS, and an additional 24 states have developed science standards derived from NGSS. As 71% of students in the United States are currently receiving or are in the process of transitioning science instruction to be NGSS-based (National Science Teacher Association, 2020), the ability for public education to implement the complexities of NGSS will directly depend on the structures of professional learning executed with science educators. The NGSS differs from traditional science standards as a three-dimensional approach consisting of science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) (Janszyk et al., 2016). The three dimensions of NGSS are intended to be interwoven into all aspects of student instruction to aid in the building of a conceptual understanding of how and why the world works.

According to Sisman (2016), a relationship exists between the leadership skills of school principals and school effectiveness. A school principal and instructional coordinators' aptitude to productively support the implementation of NGSS can be influenced by their understanding of three-dimensional scientific teaching and learning (Iveland et al., 2017). Therefore, the conceptualization of three-dimensional instruction, guided by school principals and instructional coordinators, requires their deep understanding of content knowledge and explicit translation of the three dimensions of NGSS to engage science educators.

To prepare students for 21st century postsecondary education and employment, it is essential that school leadership actively seek to build equitable science courses and professional learning opportunities for science educators (Jang, 2016). Rillero (2016) explained that the NGSS was designed to encompass a prominence of deep conceptual understanding, with students engaging in scientific learning as the scientist and engineer. The shift to three-dimensional, NGSS-based teaching and learning requires a focus on phenomena-based storylines. Educators are asked to move away from teaching about science and instead allow the student to figure out science (Schwarz et al., 2017). There is a gap in applying three-dimensional lessons during NGSS instruction in early implementation states, created by variations in professional learning, instructional materials, and school-based expectations (Tyler & DiRanna, 2018), which distinctly applies to the implementation of NGSS in the state of New Mexico. Numerous educational stakeholders in New Mexico have continuously advocated for advanced support in NGSS implementation since the adoption was formally announced (Legislative Education Study Committee, 2018a). Communication of the lack of professional development, content knowledge, three-dimensional integration, and instructional resources indicates a significant gap in instructional practice in secondary science classrooms across the region. Realizing the vision for the NGSS will require professional development for all stakeholders to build capacity for science educators to implement phenomena-based instruction and the development of coherent progressions of scientific concepts (Tuttle et al., 2016).

Purpose of the Study

The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. New Mexico formally adopted NGSS in November 2017, with statewide K-12 implementation mandated beginning in July 2018 (New Mexico Public Education Department, 2018). Through the adoption and implementation of NGSS, districts and schools face challenges, including building teacher capacity, developing instructional materials, and communicating the expectations of the standards with the community through professional learning and coaching structures (Woulfin & Rigby, 2017). As public education systems throughout this country have already embarked on NGSS implementation since 2014, a negligible quantity of literature exists to guide recently adopted states. As New Mexico engages NGSS-based science instruction, this study collected insights from participants on the process of implementing three-dimensional teaching and learning. Obtaining the perceptions of those in the field of education responsible for implementing NGSS may provide meaningful data on processes beneficial to enhance science instruction further, and therefore, students’ scientific literacy, which may have local, regional, and global economic implications.

Research Questions (Qualitative)

The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. The following research questions align with the problem, purpose, and conceptual framework of this study.

1. RQ1: What are the perceptions of school principals, instructional coordinators, and science educators regarding the effectiveness of the strategies they have used to implement NGSS in four New Mexico school districts?
2. RQ2: What are the perceptions of school principals, instructional coordinators, and science educators regarding the barriers and challenges they have experienced in implementing NGSS in four New Mexico school districts?

Conceptual Framework (Qualitative)

The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. A conceptual framework provides a context to analyze data through theoretical foundations (Ravitch & Carl, 2016). The paradigm of adult learning indicates that an individual's awareness of a gap in their current understanding can transform into a catalyst for new knowledge. To address the multi-faceted process required to implement innovative education standards, such as NGSS, sensemaking will support the theoretical framework. In contrast, the conceptual framework for this study is influenced the *Framework* (National Research Council, 2012) to support both the perception of participants' experiences and alignment to NGSS expectations.

Sensemaking theory “refers to how people notice, selection and interpret ideas in their environment, but also how they enact them, to be rendered meaningful” (Rom & Eyal, 2019, p.63). Introduced by Weick (1995), based on the earlier work of Schön (1983), sensemaking is the ability to create a shared understanding and encompasses an essential requirement of educational leaders and educators (Brewer, 2016). Implementation of NGSS requires novel learning of the *Framework* (National Research Council, 2012), the standards, and their implications for the instructional shifts necessary for students. Through learning, individuals enhance creativity, adapt, and expand opportunities (Pescaru, 2019). Consideration in the perceptions of principals, instructional coordinators, and science educators in this context necessitates using a lens of sensemaking to gain insights into their learning process and perceptions.

Explicit guidance of what the student learning process for science should look like is purposely designated in the *Framework* (National Research Council, 2012); however, it provides little guidance on accomplishing this goal (Russ & Conlin, 2017). In addition to learning the new standards, individuals engaged in NGSS implementation must transform their knowledge into actionable instruction aligned to the expectations of NGSS. This study leveraged the purposeful infrastructure of the NGSS as the researched-based structure to guide the conceptual framework of this investigation. The analysis of participant perceptions, the extent of the alignment to the *Framework* (National Research Council, 2012), and sensemaking theory (Schön,1983; Weick,1995) supported how science education stakeholders perceive the implementation of NGSS. The narrative reporting through this qualitative inquiry worked to make meaning of principals, instructional coordinators, and science educators' experiences and provide possible implications for future implementation processes.

Nature of the Study

"Children are born investigators" (National Research Council, 2012, p. 24), and therefore the role of making meaning from experiences cannot be underestimated. This study embraced the investigatory nature of student learning opportunities in science by examining perceptions of NGSS implementation practices. The study was approached through an exploratory case study to support the endeavor to investigating phenomena of NGSS implementation based on the perceptions of three distinctive sub-groups of NGSS stakeholders. I conducted interviews with three principals, one instructional coordinator, and four science educators from four New Mexico school districts through this qualitative exploratory case study. To comparatively conduct a data sort from each of the three sub-groups of participants, transcripts of the interviews were created. Provisional and open coding was used for the identification of classifications and themes. Finally, emerging relationships between categories and sub-groups was used to examine the data and create a narrative to explain the phenomenon under investigation (Rubin & Rubin, 2012).

Participant recruitment and selection was conducted through purposeful sampling strategies of secondary education principals, instructional coordinators involved in NGSS implementation, and sixth through 12th grade science educators. Semi-structured interviews were conducted with participants to obtain the data required to address the study's research questions. Based on the current recommendations from the Centers for Diseases Control and Prevention (2020), interviews were conducted via secure video conference forums to ensure the safety of participants and the researcher during the COVID-19 pandemic.

Definitions

Content knowledge: Content knowledge refers to the frame of knowledge, from an identified science domain, provided to students through instruction to develop skills, abilities, and conceptual understanding (Mikeska et al., 2018). It includes scientific facts, concepts, and theories in life, physical, earth and space, and engineering domains, in which students are expected to demonstrate mastery of their content knowledge after specified instruction.

Next Generation Science Standards (NGSS): Based on the National Research Councils *A Framework for K-12 Science Education* (National Research Council, 2012), the NGSS are science and engineering content standards-setting learning expectations through practices, content, and domain connections for all students. Designed by lead states and science educational stakeholders, they aim to provide performance expectations aligned to rigorous sensemaking of real-world observations and application for problem-solving (Huff, 2016).

Phenomena: In NGSS, phenomena involve an anchoring observation, including measurement of real-world events that are used to engage students in questioning and relevance in the science content presented (Hancock & Lee, 2018).

Three-Dimensional: This refers to the three components of NGSS, including (1) SEPs, (2) DCIs, and (3) CCCs. NGSS employs an integrated approach to address the complexities of the conceptual understanding of science, in which all three dimensions are simultaneously incorporated in student instruction (Krajcik, 2015).

Assumptions

It is assumed that the study participants are full-time licensed staff in good standing with their school district and hold the position stated. It is also assumed that the principals, instructional coordinators, and science educators will accurately answer the interview questions and to the best of their ability. Principals will be believed to serve in a high-quality instructional leadership role at their school, instructional coordinators will have supported NGSS implementation, and educators will currently teach at least one section of secondary science. Working under these assumptions facilitated the investigative exploration of the research questions.

Scope and Delimitations

The study focused on NGSS implementation in New Mexico to gather data not currently available on stakeholder perceptions of the implementation process. The investigation in this research is limited to the identified features of the target population, consisting of full-time secondary principals, instructional coordinators in site-based or central office science support roles, and science educators who are actively pursuing NGSS-based instructional practices in science classrooms. Populations excluded from the study will be districts and individuals who have not actively worked to transition to NGSS. Although a critical component of the *Framework* (National Research Council, 2012) and NGSS, the study was limited to perceptions of implementation and did not examine three-dimensional science instruction's effectiveness. Sensemaking (Schön, 1983; Weick, 1995) was used as the foundation for the theoretical framework. The *Framework* (National Research Council, 2012) was used as the conceptional framework to establish the boundaries for the exploration of NGSS implementation. Insights gained from the study may be transferable to similar secondary science settings, with possible direct implications on principals and instructional coordinators.

Limitations

The study was limited to the constraints of the population examined concerning the research questions. District implementation of NGSS was limited to alignment with required timelines of the New Mexico Public Education Department for implementation of NGSS in grades K-12 by July 2019, funding allotments, and district-specific expectations. The study was also limited to the responses to interviews provided to the participants, capturing perceptions of NGSS implementation within the limitation of the study parameters. The interview questions were peer-reviewed before conducting the study to address potential biases in the questions. Additionally, conducting data collection during the COVID-19 pandemic presented limited factors on the participant sample size and necessitated a virtual interview format.

Significance

This study may address a gap in practice exhibited in implementing the new science instructional standards and the ability for science educators to engage students in three-dimensional science instruction. This study addressed a local problem, with national implications, by focusing on the perceptions of principals, instructional coordinators, and science educators in the implementation of NGSS. Assessing pedagogical content knowledge and confidence in the ability to enact the three-dimensions of NGSS, SEPs, DCIs, and CCCs, is a critical component in evaluating the success of NGSS (Kang et al., 2018). This project is an original contribution, as the data acquired will occur synchronously with the initial application of NGSS in New Mexico classrooms. The results of this study support Walden University's mission for positive social change and may provide vital insights into the process of executing new educational science standards into action for consideration by state and district leaders.

New educational standards are characteristically communicated in a top-down approach (Ossiannilsson, 2018). Therefore, the need for administrators to have a clear understanding of NGSS before relaying expectations to science educators will prevent misconceptions and distortion of their intention. The study's findings may have a direct significance on NGSS rollout procedures and provide wisdom on the professional learning required for principals and instructional coordinators to encompass the capability to contribute knowledge for science educators to metamorphize teaching to NGSS. Supporting teachers to enact this shift will necessitate much more than traditional forms of professional learning communities and intermittent professional development sessions (Gouvea & Passmore, 2017). As the interdisciplinary nature of STEM continues to accelerate in the workforce, the NGSS aims to advance scientific literacy (Ames et al., 2017). Therefore, NGSS provides the opportunity to evoke direct positive social change in 21st-century skills as they enter postsecondary pathways.

Summary

This chapter offered an introductory preview of the study by providing the context and discussion of the present-day concerns confronting the implementation of NGSS in the secondary setting. Compliance with the NGSS mandate is a fixed expectation. However, readiness by principals, instructional coordinators, and science educators to carry out the directive may not be appropriate based on their instructional background, skill sets, and knowledge of three-dimensional learning. Facilitating a significant science educational reform must be backed by well-informed leaders who can translate NGSS instruction into continuous professional learning and classroom structures.

Limited information is available on the perceptions of key stakeholders in the implementation of NGSS. I sought to gain insight on this topic to inform future NGSS implementation mechanisms in K-12 educational settings. Sensemaking (Schön, 1983; Weick, 1995) provided the theoretical framework to guide the study and analyze the data collected from the investigation. At the same time, the *Framework* (National Research Council, 2012) served as the conceptual framework to interpret the perceptions specific to NGSS expectations. Insight on the implementation of NGSS in science may give strategic guidance on the continued effort to transform science classrooms and increase student literacy to impact the STEM pipeline.

Chapter 2 will provide a comprehensive review of current literature related to NGSS, science education, and principal leadership. Detailed information on the conceptual and theoretical framework for the study supported the phenomena under investigation. The research provided will demonstrate clear relevance to the problem and support and address the gap in practice under investigation.

Chapter 2: Literature Review

Within the current transitional state of science education, there is a need for an increased understanding of the essential components leading to the successful implementation of NGSS in the secondary setting. “The majority of Americans learn most of what they know about science and engineering as middle and high school students” (National Academy of Sciences, Engineering, and Medicine, 2019, p. 1). Therefore, critical importance is placed on conducting investigations capturing the current structures to instruct secondary students in the content area of science. The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. Through this investigation, insight gained can guide the implementation of NGSS in New Mexico school districts, with possible applications to all science education institutions employing three-dimensional learning.

The modernization of K-12 science education by the *Framework* (National Research Council, 2012*)* and NGSS is intended to guide the transformation of science classrooms into engaging experience-based conceptual learning environments. “In a rapidly changing, information-rich world, it makes sense for a contemporary education to prepare students to transfer their learning to confront unpredictable challenges and opportunities” (Wise & McTighe, 2017, p. 18). As a relatively new educational structure, NGSS is still in the early stages of implementation nationwide and lacks a robust research base on student learning outcomes. Additionally, contrasts in how to best approach the transition to NGSS are noted by Windschitl and Stroupe (2017). They argue that the traditional alignment method will not address the pedagogical needs of teacher transition. The challenge presented by NGSS is best responded to by a collective group of principals, instructional coordinators, science educators, and community members working together to progress thoughtfully and cognizant of deviations from current practice (Floden et al., 2017). Future studies are needed to explore the effectiveness of professional development provided by principals and curriculum specialists on teacher expertise in NGSS and correlations to changes in classroom science instruction (Reiser, B. et al., 2017). Further complicating NGSS implementation is a lack of evidence-based training and tools for principals and program evaluators to evaluate three-dimensional science instruction (DeBarger et al., 2016).

This chapter presents an evaluative examination and synthesis of the relevant literature on NGSS implementation, focusing on the role of principals, instructional coordinators, and science educators. Initiated by an exhaustive review of literature, I determined themes based on the current evidence on science educational reform, teacher training, and three-dimensional learning. Emphasis on the perceptions of principals, instructional coordinators, and science educators NGSS implementation provided a lens to examine the research within the field. Evidence gathered reflects the significance of sensemaking (Schön, 1983; Weick, 1995) in transitioning educational expectations. Findings in the literature were helpful in evaluating the current state of science education, coherence of NGSS implementation in various settings in New Mexico, and the importance of instructional support to enact science education reform. This evidence was viewed through a reflective lens and sought to determine the measures necessary to employ the implementation of the *Framework* (National Research Council, 2012*)* and NGSS.

Literature Search Strategy

The strategic search term was identified to concentration the literature review on relevant and reliable resources. The keywords *NGSS, three-dimensional, science phenomena, secondary science instruction, instructional leadership, sensemaking, science content knowledge, secondary principal, principal science supervision, science educators, instructional coordinators,* and *STEM learning* were searched using the Walden University library and the Google Scholar search engine, including ERIC and EBSCO. An exhaustive literature search on NGSS implementation and the role of principals and instructional coordinators in NGSS implementation yielded a limited number of studies investigating initial implementation outcomes of NGSS and their impacts on instructional practice. Thus, a gap in practice is indicated.

Conceptual Framework/Theoretical Foundation

Developing insight into the implementation of NGSS requires understanding the learning process employed by adult learners necessary to embark on this transition. Motivated by the guiding principles of the *Framework,* NGSS was built upon the following beliefs: (1) children are instinctively investigators; (2) content, practices, and themes must be integrated into three-dimensional science learning; (3) understanding develops over time; (4) science and engineering require both knowledge and experiences; (5) learning requires a connection to student interests and skills; and (6) one must provide all students with equitable opportunities to engage in scientific learning (National

Research Council, 2012). The translation of these principles into direct student instruction denotes those responsible for implementation can design three-dimensional learning experiences for educators during professional learning and students and thus have a conceptual understanding of NGSS. Therefore, the *Framework* (National Research Council, 2012) as the conceptual framework supported the alignment of participant perceptions to NGSS. Sensemaking (Schön, 1983; Weick, 1995) provided the lens for how principals, instructional coordinators, and science educators perceive their personal learning experiences.

As a continually changing global world continues to shift the workforce demands, educational settings need to modify the focus from memorization of content to constructivist-based acquisition of skills and 21st-century competencies (Barak, 2017). However, according to Jitka et al. (2018), research indicates that most teachers do not effectively use experiential pedagogy in their lesson development and teaching. With ties to Socrates' active learning practices, Dewey (1933) advocated for learning in schools to be an experiential, real-world process. Further supporting the view that learners must construct their knowledge, Piaget (1972) argued that learners create awareness for themselves in a discovery-based and individualized approach. In a culmination of previous work, Vygotsky (1978) determined that constructing knowledge must be built upon an individual's prior experience and the reconstruction of the relationships with their prior understanding. Supported through the work of Bruner (1990), an educator's instructional impact is the greatest when their professional learning is facilitated through the forum of experiential learning.

In association with constructivism, sensemaking (Schön, 1983; Weick, 1995) benefited the study for providing a context to support how participants rationalized their experiences. Implementing the revised science standards requires the acquisition of new knowledge of NGSS by principals, instructional coordinators, and science educators. Emphasized through Schön's (1983, 1987) published works, the theory of reflective practice inquiry provides a context for how educators explain their learning. Weick (1995) enhanced the work of Schön (1983, 1987) by introducing the terminology of sensemaking to describe the development of shared meaning through frameworks that facilitate understanding and support the synthesis of meaning. The ability to decipher cogitative gaps and transform them into narratives and mental maps is a critical component of sensemaking. It reinforces the explanation of how people extract meaning from experiences (Rom & Eyal, 2019). This study's use of sensemaking (Schön, 1983; Weick, 1995) as the theoretical framework assists with analyzing and interpreting the data by providing the contextual lens to support the understanding and explanation of participants' responses.

Literature Review Related to Key Concepts and Variable

In this literature review of evidence-based findings from peer-reviewed journals, I reviewed variables that influence the effective implementation of the NGSS, as outlined by the *Framework* (National Research Council, 2012). Using current literature from the previous 5 years, I conducted a comprehensive review between the relationship between NGSS and implementation practices through a diverse collection of research and perspectives. Impacts on the variables related to the realization of NGSS in secondary science classrooms and leadership were also considered concerning the teaching and learning cycle and pedagogical content knowledge. Additionally, I analyzed professional learning structures to enhance current information adult learning for principals, instructional coordinators, and science educators.

The structure of this literature review is outlined in a format that follows the organizational structure of the NGSS implementation process (National Research Council, 2015), beginning the foundation of the standards and then progressing towards the conceptualization of NGSS-based instruction: (a) NGSS foundations, (b), integrating three dimensions of NGSS, (c) phenomena-based instruction, (d) leadership, (e) effective professional learning, (f) NGSS implementation, (g) assessment, and (h) equity. Studies were examined to identify the meaning and central premises within the context of NGSS implementation and science instruction. The present-day indicators of the defined variables which have significance to the role of principals in NGSS implementation were acknowledged, and the relevant findings are represented.

NGSS Foundations

The vision of NGSS emphasizes the importance of a systemic progression of problem-solving, sensemaking, and communication skills from kindergarten through high school (Campbell et al., 2016). As a countermeasure to the established culture of high stakes testing, singular focus on mathematics and literacy, and historically low science proficiency rates, NGSS requires active classroom experiences to engage students in investigations on the natural world and necessitates why future science learning must look different (Windschitl & Stroupe, 2017). Quality science instruction, directed by the

Framework (National Research Council, 2012) and NGSS, requires administrators and teachers actively working to build children's curiosity about the world and develop the requisite skills necessary to succeed in the ever-increasing STEM-integrated career pathways (Isabelle, 2017). STEM industries are responsible for 50% of the sustained economic growth, yet STEM professionals only make up 5% of the U.S. workforce (Bautista et al., 2018). Holding an international ranking of 38 out of 71 in science and mathematics (Desilver, 2017), the United States public has a consensus that a dramatic improvement in the way science is taught is needed. However, the implementation of NGSS is to meet with inadequate resources to sustain the professional development and resources required to shift instructional practices (Harris et al., 2017).

Although the significant base of science content is unchanged from previous standards, engineering is a substantial innovation of the NGSS. While scientists study the natural world, engineers design solutions to problems to modify the world to better meet human needs (Whitworth & Wheeler, 2017). Current science education structures cannot be amplified or modified to become NGSS; instead, a systematic conversion is required (Harris et al., 2017). Patterson (2018) asserts that teachers need to acclimate to three-dimensional instruction. Principals and instructional coordinators must make a concerted effort understand information necessary to embrace and encourage active learning classrooms with very little direct instruction. Often seen in educational reforms, Hoeg and Bencze (2017) identified a discrepancy between the intent of NGSS and the current practice in classrooms, which presents a challenge to correct. Existing literature on the foundations of NGSS distinctly denotes a substantial difference in the organization and objectives of the science standards compared to previous versions. The evidence indicates the need for a paradigm shift is imperative to successful NGSS implementation; however, examples of authentic achievement of comprehensive NGSS state-wide transition are rare in the prevailing literature. The theoretical aspects of why students must increase scientific literacy and a more robust STEM workforce are specified. Still, the research presents gaps in the best approaches to ensure funding, instructional materials, and professional learning to meet the needs of NGSS implementation.

Integrating the Three Dimensions of NGSS

A significant consequence of NGSS should involve the evolution of science classrooms from places where students learn about science to students applying science and engineering to figure out the mechanics of how our world works (Passmore, 2015). The *Framework* (National Research Council, 2012) and NGSS envision science education as both a body of knowledge and a set of practices to develop an understanding (Penuel et al., 2015). The SEPs, DCIs, and CCCs work in an interconnected nature to activate the multi-dimensional approach required to learn science and engineering conceptually. The SEPs represent the actions that scientists and engineers employ in their work. The CCCs are themes critical for connecting background knowledge to new learning in science. The DCIs are the traditional content students are expected to know and understand. Compartmentalizing or separating the three dimensions of NGSS can lead to misconception and a lack of conceptual content understanding for educators and students (Houseal, 2016).

A central premise in both the *Framework* (National Research Council, 2012) and NGSS is three-dimensional learning, characterized by scientific inquiry organized into eight SEPs and seven CCCs, which connect to the DCIs within each grade band (Jin & Mikeska, 2017). Although three-dimensional learning consists of complexities not yet to be fully addressed in most science classrooms, McComas and Nouri (2016) argued that teachers must also include the nature of science (NOS) components of the *Framework* (National Research Council, 2012) even though NOS is not specifically designated within each NGSS standard. Addressing common student misconceptions about the intricacy of the relationship between science and technology can be solved by helping students to understand the application of NOS (Pleasants, 2017). However, it would add a fourth dimension to an already complex group of science standards under this context.

In a technology-rich society flooded with information mingled with personal opinions, the ability to reason through the accuracy of scientific claims is an increasing societal need. Supporting critical thinking as a countermeasure to misinformation and non-scientifically based claims can be accomplished by applying the NGSS SEPs (Zucker, 2019). The origination of three-dimensional learning introduces a leveled ground, where all students have an entry point to content, and collaborative learning can occur. In a science classroom, failures should be viewed as extended opportunities to learn and a critical part of the scientific and engineering process (Lottero-Perdue & Perry, 2019). Conversely, a fragmented curriculum, decreased planning time, and failure to invest in the resources create a system not prepared to support three-dimensional science learning (Anderson et al., 2018). Enactment of the three dimensions of NGSS, seamlessly integrated, is a challenging accomplishment but yields deep scientific understanding and productive citizen scientists (National Academies of Science, Engineering, and Medicine, 2018a). Although the literature overwhelmingly supports the model of three-dimensions in science instruction, it does not address practical guides on how to transform one or two-dimensional instructional materials into three-dimensional resources aligned with NGSS. According to The National Academies of Science, Engineering, & Medicine (2018b), NGSS-aligned instructional materials are still not readily available for purchase or digitally. Thus, educators will continue to struggle to design and implement interlocked three-dimensional science instruction in the absence of a three-dimensional curriculum and resources.

Phenomena-Based Science Instruction

Promoted within NGSS, phenomena-based science instruction engages students in an investigation or observation of a naturally occurring event. The phenomenon should be initiated at the beginning of a topic to create a culture of shared learning, connections to individual’s background knowledge, an opportunity to ask questions (Deverel-Rico & Heredia, 2018). According to Krajcik (2015), the characteristics of selected science phenomena should include: (a) feasibility for investigation, (b) be worthwhile to question, (c) contextualize a real-world observation, (d) make a meaningful connection to students, € be sustainable throughout the course through connecting to multiple contexts, and (f) meet ethical standards. As learning is a social practice, developing a complex learning network that evokes children to think and connect with the natural world serves to strengthen their interests in science and develop environmental identities (Tugurian &

Carrier, 2017). In this context, Tichnor-Wagner (2017) encourages all classrooms to become places of global citizenship. Students are tasked to solve real-world problems and cultivate complex understandings beyond their local environment.

The use of a storyline introduces a phenomenon at the start of a unit and then carry the theme of the phenomena throughout the learning progression. NGSS exchanges the simple recall of a long list of isolated facts with a focused set of core ideas, organized into articulated learning sequences engaging students in meaningful phenomena through questioning (Holthuis et al., 2018). The key to phenomena based, three-dimensional NGSS instruction is to ensure students are asking questions and seek answers to their questions throughout the learning process. Teacher-facilitated science investigations conducted through the lens of real-world phenomena of interest to students create a compelling unifying influence that drives student learning (National Academies of Science, Engineering, and Medicine, 2019). Positioned as a powerful mechanism in NGSS learning, phenomena-based instruction embodies the learner-centered classroom and engages students in relevant and stimulating knowledge acquisition. Unfortunately, as with many other aspects of NGSS, insufficient resources exist to support phenomenon ideas and storyline progressions for science educators.

Leadership

Educational administration and leadership research historically represent a change-focused schema, consistently articulating dissatisfaction with the status quo (Eacott, 2017). Variables such as school environment, organizational commitment, job satisfaction, and student achievement show a correlation to instructional leadership

(Sisman, 2016). Far too often, school principals' explicit and implicit communication does not consistently promote inventiveness, creativeness, and risk-taking in STEM classrooms (Harper, 2017). The authentic leadership construct, identified as a leader having self-awareness, balanced processing, internalized moral perspective, and relational transparency, demonstrates a correlation with an individual's level of emotional intelligence (Duncan et al., 2017). As stated by Tomlinson and Murphy (2019), "The principal plays a key role in seeking out and providing the kind of support teachers must have to understand and develop comfort to work from the point of empathy" (p. 26). The ability to skillfully self-reflect helps a principal to focus on their work, motivates cognitive effort, and fosters professional growth towards transforming a school (Ersozlu, 2016). In staffing science classrooms, to meet the needs of NGSS, principals must also consider each teacher's mathematics, technology, and engineering backgrounds to determine STEM professional learning needs (Ames et al., 2017).

The role of the school principal enacts a delicate equilibrium between development and accountability. A study conducted by Lochmiller (2016) confirmed that most feedback provided by principals to math and science teachers focused on generalized pedagogy and is founded in the administrator's classroom experience. Educators then believe that principal-based feedback does not apply to their specific instructional needs and lacks the specificity required to change practice. Instructional coordinators, either central office or site-based, traditionally support structures within a district to enhance instructional practices. Individuals in the position of an instructional leader should actively work to increase the coherence in instruction through structured professional learning and job-embedded coaching for teachers and administrators (Woulfin & Rigby, 2017). School leaders should also limit non-instructional operational job requirements for teachers to provide more time for lesson design and parent communication (Kraft, 2018).

Teachers are not policymakers. Nevertheless, they encompass the knowledge and experience to lead change based on the guidance and resources (National Academies of Science, Engineering, and Medicine, 2017b). Leadership school, district, and at the state level is a critical component of the educational system. The Public Education Department, tasked with overseeing and support the education of children in New Mexico, has been found to not sufficiently fund schools or provide the oversight needed for school districts (Legislative Education Study Committee, 2018b). The Yazzie & Martinez vs. State of New Mexico lawsuit also found fault in the state legislature for allotting funds for education based on availability rather than sufficiency (Legislative Education Study Committee, 2018b). Community organizations, such as the League of Women Voters of New Mexico, have issued statements urging the need for continued court oversight to ensure the intended outcomes of the Yazzie & Martinez vs. State of New Mexico lawsuit is upheld and that schools will be provided with the funds and resources required to support equitable learning environments (Vanwie, 2020). As the state of New Mexico has been presented with continued challenges to its educational system, principals and instructional coordinators are continually tasked with ensuring the learning of students, operation of school buildings, and support for educators.

Effective Professional Learning

The indication of an immense gap between current practice and strategies advocated by the *Framework* (National Research Council, 2012*)*, can be remedied by high-quality professional learning designed for coherence to NGSS, connect to teacher background knowledge, and are goal orientated (Nollmeyer & Bangert, 2017). The release of new educational standards is often slow to cause change. Evidence indicated this is due to a lack of adequate professional development and insufficient timelines for implementation, explicitly when the mandates contain new content for teachers, such as the engineering components of NGSS (Judson et al., 2016). For science educators to effectively meet students' learning needs, they must have abundant content knowledge in their given subject, high pedagogical comprehension, and the ability to integrate the two seamlessly (Slough & Chamblee, 2017).

Furthermore, secondary teacher's science identities are directly translated to their students' scientific identities, which should be a consideration for teacher preparation and professional learning programs (Chung-Parsons & Bailey, 2019). To deliver three-dimensional instruction, science educators will require a long-term professional development process to gain a sophisticated understanding of NGSS (Melville et al., 2015). "Teacher education and professional development will play a big role in whether our nation's students achieve the goals embraced by the *Framework* and NGSS" (Hoffenberg & Saxton, 2015, p. 28). Research indicated that a teacher's science content knowledge is a crucial factor in their ability to engage students in three-dimensional learning, including the ability to differentiate instruction and modify resources (Mikeska et al., 2018). The extensive pedagogical and conceptual shift that NGSS has placed on teachers requires participation in problem-based learning (PBL) professional development experiences to strengthen understanding of and ability to enact the NGSS learner-centered instruction (Shernoff et al., 2017). Teachers require strategic and consistent learning opportunities that enhance their knowledge, practices, and attributes needed to meet the current needs, and future professional requirements (Luft & Whitworth, 2019). A study conducted by Tuttle et al. (2016), indicated that after one year of NGSS professional development, teachers would require ongoing support, including coaching and embedded learning opportunities, to implement the new teaching methods fully. PBL uses teachers in engaging learners in SEPs, DCIs, and CCCs in an integrated nature to solve real-world problems by making sense of phenomena (Touitou et al., 2018).

NGSS establishes a strong emphasis on sustainability and climate change. Conversely, most science teacher's college courses did not include Earth and space science content beyond an introductory course (Egger et al., 2017). NGSS includes specific measures for the advanced communication structures required for scientists and engineers to share their findings. Consistent writing instruction is unlikely to be included and therefore devised to fit within a strategic process of teacher support (DeBose Akinnagbe, 2018). Findings indicate that the teacher's emotional connection to a professional development experience directly correlates to the transferability of the learning (Gaines et al., 2019). Due to the recent adoption of NGSS, Kang et al. (2018) cite a lack of current research specifying the level of teacher pedagogical content knowledge of the SEPs and DCIs. Consequently, the catalyst of change needed for NGSS can be supported by relevant professional development or hindered by bad experiences.

The role of the school principal enacts a delicate equilibrium between development and accountability. As it is not feasible for all administrators to be content-area experts in all subjects and grade bands, a prosperous school-wide leadership plan includes identifying support staff members to assist in designing and implementing targeted professional learning (Woulfin & Rigby, 2017). Additionally, to manage the difficult task of balancing instructional leadership and operational requirements, principals who leverage teacher leaders and instructional coordinators to carry on their vision of professional learning are more successful at creating a sustainable platform for advancing teacher quality and, therefore, student achievement (Johnson, 2016). In early implementation, states and districts that are effectively execute NGSS instruction increased quality principal and teacher leadership is evident as the most significant contributing factor (Pruitt, 2014).

NGSS Implementation

A coherent, integrated, and three-dimensional system comprised of curriculum, assessment, and professional development working in coordination is vital for realizing NGSS (Huff, 2016). The processes of teaching and learning must meet the full range of students in classrooms throughout the country. As an estimated third of high school graduates will immediately enter the workforce instead of post-secondary education, lesson design should reinforce the transfer of knowledge, problem-solving, and digital citizenship (Murray, 2019). Glaze (2018) also applies this concept to current undergraduate STEM programs, stating that graduates will enter the workforce with incomplete and inaccurate understandings of their fields without higher scientific literacy and inquiry skills built into the curriculum. The concept that students need to achieve a conceptual understanding of science is accepted through a generalized consensus in the scientific community.

Nevertheless, an applied framework to support this idea's realization is still yet to be achieved (Papadouris & Constantinou, 2017). Although most pre-NGSS resources may address some elements of the dimensions, all instructional resources must be evaluated to determine three-dimensionality and should be built towards a bundled group of NGSS standards (O'Day, 2016). Most existing lessons will not be adequately aligned to NGSS or appropriately address all three dimensions (Golan Duncan & Cavera, 2015).

An additional challenge is the historical use of textbooks as the primary curriculum by most secondary science teachers. Specifically, science textbooks have long been criticized for covering too many topics, including misconceptions, errors, and oversimplification (Smith et al., 2017). According to Jin and Mikeska (2017), "designing NGSS-aligned activity sequences is one of the major challenges facing K-12 science teachers" (p. 66). Asking students to develop models for scientific explanation should be positioned as the goal under NGSS, rather than a traditional method of developing models of science that provide one-dimensional understanding (Gouvea & Passmore, 2017). The use of instructional models, such as the 5E model (Bybee, 2013), can help students progressively refine their understanding of science and engineering (Forsythe, 2018).

Additionally, the curriculum cannot just be considered solely based on current teachers' instruction. Pre-service teacher education programs need to reconsider their curriculum aligned to NGSS to prepare science teachers for the NGSS standards they will be expected to implement upon entering the classroom (Hanuscin & Zangori, 2016). A significant gap exists in supporting students to construct scientific explanations about the phenomenon and CCCs utilized in instruction has been observed in teaching candidates (Richmond et al., 2016). Echoing the concern for teacher preparation programs, Riley and Sakimura (2018) support the need for alignment between pre-service teacher experiences and structured classroom expectations. Implications from this finding suggest the new science teachers will struggle to implement three-dimensional instruction. Aligned to the *Framework* (National Research Council, 2012*)*, making scientific products through design, invention, and the building is an impactful way to have students explore science concepts and phenomena (Rodriguez et al., 2018). The inclusion of data literacy and scientific communication is an increasingly crucial component of student learning and NGSS. It is encouraged to be accomplished by analyzing local and authentic data sets (Forester et al., 2018).

Learning under a three-dimensional model takes additional time than when instruction is only covering content. Therefore, teachers will need support in adjusting time management to gradually engage students in scientific practices and consciously allow intervals of classes to investigate questions (Colson & Colson, 2016). As a guide to principal's and instructional coordinators, Prendergast (2018) states that during classroom observations, an NGSS-based environment should: (a) have students engaged in an anchoring phenomenon which is revised consistently to build levels of understanding, (b) be filled with student-to-student interaction and discussion, (c) clear models of student-generated thinking that are revised with each progression of the unit, and (d) all members of the classroom use evidence to communicate and support their ideas.

Assessment

In response to the implementation of NGSS, states, school districts, and schools, a sweeping overhaul of science assessment is required to assess students three-dimensionally and in alignment with classroom instruction. The transformation of science assessments will require innovation and systemic changes by each state, including summative and formative assessments embracing coherence with NGSS (Achieve, 2018). “To gauge different types of learning, we need a broader collection of measures, with a greater emphasis on authentic, performance-based projects” (McTighe, 2018, p. 14). Unfortunately, well-defined guidance on developing NGSS-based assessment is absent from the *Framework* (National Research Council, 2012) and NGSS. It leaves teachers with the challenge of creating student mastery checks that provide clarity, rationality, and causality within science content (Russ & Conlin, 2017). Assessments in NGSS are determined by each standard, or bundle of standards, performance expectation(s), and the evidence statements. The performance expectation indicates the assessment required for a student to demonstrate mastery. In creating an NGSS-based assessment, the evidence statements should be consulted for a pure and unaltered view of the observable expectations to demonstrate student mastery (German, 2017).

The ambitious expectations set forth by NGSS do not change only teaching practices but also compels the creation of a three-dimensional evaluation of student learning through formative assessments (Furtak & Heredia, 2016). A recent study in a college setting demonstrated increased student retention of science content when students were given a collaborative multiple-choice exam, requiring them to work in groups to justify answers (Newton et al., 2019). The use of formative assessments, such as exit tickets, can be beneficial in gauging student learning. However, educators should invest the time to use the data collected to adapt instruction through reflection and action (Fowler et al., 2019). To assess the intended performance expectations of NGSS, three-dimensional instruction must be followed by a three-dimensional assessment that either has a sequential, concurrent, or embedded model to determine levels of mastery on each component of the SEP, DCI, and CCC (Cian et al., 2019). In a recent analysis of the NGSS, 46% of all performance expectations for K-12 require data skills (Finzer et al., 2018). As curriculum and instruction directly affect learning paths, quality assessments are necessary to ensure learning progressions (Osborne et al., 2016). The understanding by design model requires the assessment to be designed before the instruction sequence, and NGSS work in concert to ensure alignment to the performance expectations and a strategic focus on student mastery (Sumrall & Sumrall, 2018).

Equity

A diverse 41-member writing team conducted the translation of the *Framework* (National Research Council, 2012) into NGSS. It included an equity subgroup that ensured the coherence of all standards for all students was deeply entrenched within the standards (Januszyk et al., 2016). An outcome of the equity subgroup includes the NGSS Appendix D, offered as a supplement to the standards to provide practical strategies meeting the needs of underrepresented groups of students in science classrooms (Lee et al., 2014). To address achievement gaps demonstrated in non-dominant groups, NGSS fosters the inclusion of culturally relevant pedagogy, community involvement, multimodal experiences, and a common set of expectations for all students (Strachan, 2017). A gender gap in STEM post-secondary degrees and careers is a historically persistent issue. Supportive learning environments, which foster female persistence and aptitude, demonstration confirmation of the ability to close the gender gap in STEM fields (Greitz Miller & Hurlock, 2017).

In an evaluation of 52 studies, Brown (2017) documents that the NGSS SEPs are an effective way to produce culturally responsive classrooms. Both teachers and students advanced equity of students of color, English language learners, and low-socioeconomic students through relevantly contextualized science instruction. In an NGSS environment, the explicit use of inquiry discovery-based learning can increase achievement in students with learning disabilities (Therrien & Carrier, 2017). Philip and Azevedo (2017) argue that to address the equity expectations rooted within NGSS, all students must be provided out-of-school science opportunities that bridge classroom learning and embraces authentic experiences. As a human race, we will live in a world that requires frequent scientific-based decisions, ranging from health care to the environment. Therefore, achieving scientific literacy with all students has significant implications to our society (Huff, 2016). Delivering inclusive learning experiences for all students will mandate educators to address science's social and cultural dimensions while creating classroom environments where students feel valued and safe to share and critique ideas (Kolonich et al., 2018). The premise of all standards for all students should be at the forefront of state and district implementation processes to provide equitable science education to every student.

Summary and Conclusions

The transition to NGSS-based or NGSS-influenced standards was created nationally and is currently shifting to the state, district, and school levels. A wide-ranging consensus on the need for science reform seeks to meet the needs of a growing STEM-based global economy better and advancing technological requirements for general citizenship (Bautista et al., 2018; Campbell et al., 2016; National Research Council, 2012; Strachan, 2017; & Tichnor-Wagner, 2017). This chapter offers a summary of the current research within the field of NGSS implementation. As NGSS encompasses a far departure from typical science instruction, the need for an overall structural system is evident. A systemic change must be originated by those responsible for decision-making (Ersozlu, 2016). Deep levels of understanding at the district level leadership and, therefore the building level principals are required before mandating changes.

Implications from the reviewed literature reveal the importance of equitable science education, provided to all students and designed to target the diversity of children filling classrooms across the country (Kolonich et al., 2018; Philip and Azevedo, 2017; Therrien & Benson, 2017). Professional development must target three-dimensional learning for teachers and develop a shared belief in the *Framework* (National Research

Council, 2012) and the philosophy that all students are capable of achieving a high level of scientific understanding. School leadership must set the tone of scientific excellence for all students and understanding NGSS and are consequently critical in the roll-out and implementation (Nollmeyer & Bangert, 2017; Woulfin & Rigby, 2017). Subsequently, a greater understanding of the depth of NGSS knowledge and implementation strategies principals and instructional coordinators are currently employing in the secondary setting is a critical step in generating sustainable guidance for advancing three-dimensional instruction.

Through an emphasis on the precise characteristics and needs of secondary NGSS implementation, barriers and success for transitioning science instruction were not evident in the literature. Also lacking was research on effective practices to educate principals and instructional coordinators on NGSS and guide them to create action plans on scaffolded implementation. The ability to lead is generated based on knowledge to make informed decisions (Johnson, 2016). Therefore, the subsequent chapter will outline the study’s research design and rationale to investigate the current status of NGSS implementation in four New Mexico school districts.

Chapter 3: Research Method

A review of the current literature shows a deficiency of information on the implementation of NGSS and the viewpoints of diverse science stakeholders regarding this process. Uncovering the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS will require an expansion of both content and pedagogical understanding (Houseal, 2016). The specific knowledge of principals and instructional coordinators is a determining factor in teachers' ability to increase student achievement (Sisman, 2016). Collecting data on the perceived experiences of those in education enacting NGSS implementation may support future implementation progressions. The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. This study gathered data that may provide meaningful insight into potential impacts in science education reform and the role of scientific literacy on positive social change.

This chapter is structured to communicate information related to the research method for each component of the study. The role of the researcher, research design, and study rationale are explained in detail. Descriptions of the research methodology and instrumentation are provided, in addition to descriptions of the procedures that were used to determine participant selection and recruitment, data collection, and data analysis. Finally, attention is given to validity and ethical considerations for the study.

Research Design and Rationale

The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. This study used a case study format to examine the perceptions of New Mexico principals, instructional coordinators, and teachers on the effectiveness of the initial implementation of NGSS and challenges they believe are impeding the process. Data from each sub-group of participants were triangulated using sensemaking theory (Schön,1983; Weick,1995) to elicit an understanding of how principals, instructional coordinators, and science educators perceive the implementation of NGSS. The *Framework* (National Research Council, 2012) provided the context of participant responses to the research-based foundations of NGSS. Through the use of qualitative semi-structured interviews addressed the following research questions:

1. RQ1: What are the perceptions of school principals, instructional coordinators, and science educators regarding the effectiveness of the strategies they have used to implement NGSS in four New Mexico school districts?
2. RQ2: What are the perceptions of school principals, instructional coordinators, and science educators regarding the barriers and challenges they have experienced in implementing NGSS in four New Mexico school districts?

The exploratory qualitative exploratory research design for this case study research was derived from three data points, triangulated to develop a holistic view of current practice. Data collected consisted of (1) principal interviews, (2) instructional coordinator interviews, and (3) science educator interviews. The interviews were semi-structured and investigated the phenomena of interest in the natural setting (Rubin & Rubin, 2012) and were categorized by the three groups of participants. The interviews were aligned with a qualitative exploratory case study design by gathering insights from reactions, motivations, and approaches (Ravitch & Carl, 2016) for NGSS implementation from principals, instructional coordinators, and science educators. Aligned with a purposeful sampling strategy (Creswell, 2007), demographics were collected from each participant, assessing current position in education, experience in education, content-area expertise, and current grade band. The demographic data were coordinated with open-resource district and school historical demographic data.

Cultivating students' scientific knowledge requires advanced skills in the design of three-dimensional learning experiences (Park et al., 2019). The use of experiential learning to teach science and engineering is a fundamental methodology to effectively deploy three-dimensional scientific knowledge to address the needs of all students (Asowayan et al., 2017). Therefore, the three dimensions of NGSS were considered in the perceptions of the implementation process. The study was guided by the conceptual research-based foundations of the *Framework*'s (National Research Council, 2012) five components: (1) Dimension 1: SEPs, (2) Dimension 2: CCCs, (3) Dimension 3: DCIs, (4) integrating the three dimensions, and (5) implementation: curriculum, instruction, teacher development, and assessment. Consideration of the *Framework* (National Research Council, 2012) provided the specific boundaries required to examine the perceptions of NGSS implementation, reflecting all three dimensions of the standards, integration, and application. The foundations of sensemaking theory (Schön, 1983; Weick, 1995) supported data analysis on the perceptions of principals, instructional coordinators, and science educators, and the corresponding application of three-dimensional NGSS implementation were considered through the context of the *Framework* (National Research Council, 2012).

The use of a qualitative exploratory case study was justified in this investigation due to the nature of the phenomenon under investigation and its suitable method to address multiple sources of data to establish a sequence of evidence to support the composition explanations. As Baxter and Jack (2008) explained, a qualitative case study should be used when one is focusing on research questions exploring how events occur. There is a need to cover circumstantial conditions relevant to the phenomenon. I ensured that the voice of principals, instructional coordinators, and science educators were heard by providing them with the opportunity to share their perceptions through an inductive lens and analyzing their words under the context of sensemaking theory (Schön, 1983; Weick, 1995) to support the theoretical framework. The *Framework* (National Research Council, 2012) guided the study's conceptual framework and provided a deductive lens to analyze the participant responses to the current research-based expectations of NGSS. With an awareness that a theoretical framework works as the blueprint of a research study, the addition of an interlocked conceptual framework creates an aligned and comprehensive model to support the exploration of the research questions (Grant & Osanloo, 2014). Semi-structured interviews provided the flexibility needed to ask clarifying and follow-up questions. I conducted a data sort from each of the three sub-group participants; transcripts of the interviews were created and categorized. Provisional and then open coding were used to identify classifications and themes for each sub-group. Sub-group data were compared with discerning themes existing between the diverse group of participants. The use of alternative qualitative approaches would not align with the purpose of the study and the research questions under examination. A basic qualitative design would provide a sole data point, which would not allow for the triangulation of evidence to support a multi-faceted perspective on NGSS implementation from diverse science education stakeholders.

Role of the Researcher (Qualitative and Mixed Methods)

The semi-structured interview protocol was the primary instrument for data collection. During the interviews, my role was aligned with that of an observer. I conducted interviews with three principals, one instructional coordinator, and four science educators from four New Mexico school districts. Additionally, I used open-resource, technology-based data to collect current demographics on the participating schools and districts. The districts partaking in the study represent a typical spectrum of schools throughout New Mexico, and I have not been employed in any school or district contributing to the study.

Thoughtful measures were put into place to ensure prior life experiences and knowledge do not create bias within the investigation. The prospective for researcher bias is present in any qualitative research and must be actively considered to ensure influences do not lead to distortions in the study's results (Galdas, 2017). My education career includes as a classroom teacher, professional development provider, informal science director, and central office administrator. I have taught and designed curriculum in multiple settings and a wide range of STEM-based courses, for kindergarten through my current role as a high school science teacher. I have not formally worked as a principal; however, my experience has provided me with a vast understanding of the job's complexity. In addition, I have worked at the district level as an instructional coordinator to transition science instruction to NGSS, although I was not responsible for the school-level implementation. My background in education, and specifically science instruction, has the potential to influence my research design and data analysis. To counteract any potential for background experience-based bias, I documented personal reflections in a researcher's log, paying attention to any possible preconceptions or partiality throughout the study's progression.

Maintaining alignment to the *Framework* (National Research Council, 2012), the established research design and peer-reviewed interview questions minimized potential researcher bias. In addition, interview protocols and data analysis procedures were developed and implemented to ensure uniformity in data collection. I have no personal or professional relationships with any participant, and none were provided with an incentive for their involvement in the study. The research methodology and corresponding data analysis plan will be described in more detail in the following section.

Methodology

In this section, I will provide expanded information on the participants, sampling method, and instrumentation used in the study. The description of participants incorporates recruitment, selection process, and criteria. The foundation and projected application of the instrumentation establish alignment to the purpose of the study, while the sampling method supports the intended data collection outlined for the investigation. A targeted data analysis plan showed the connection between the research questions and collected data and the procedure for coding. Finally, the study's trustworthiness and ethical considerations was addressed for transparency and reliability.

Participant Selection (Qualitative)

Three groups of participants were used for the study: sixth to 12th grade principals, sixth to 12th grade instructional coordinators (site or central office-based), and sixth to 12th grade science teachers. All participant groups were employed as a licensed educational professional in New Mexico. The participants came from four different school districts, whose settings range from rural to suburban. The districts are comprised of diverse ethnic and socioeconomic student populations, typical of New Mexico. The superintendent of each school district approved conducting the study, through the IRB process, prior to any access to study participants. Principals, instructional coordinators, and science educators were recruited through a coordinated invitation to participate with each district's office of curriculum and instruction, based on current list servers for secondary administrators, instructional coordinators, and science educators. Patton (2002) noted that purposeful sampling is the most effective way to generate information-rich data when investigating qualitative phenomena (Palinkas et al., 2015). Therefore, it was employed in the recruitment process with eight total participants.

The participant groups were identified with support from district leadership as individuals knowing about NGSS and actively pursuing the transition to three-dimensional science instruction. The purposeful sampling technique encompasses the identification and selection of research participants who have expertise in the area of investigation to gather meaningful evidence (Palinkas et al., 2015). Specifically, maximum variation sampling was used to capture a wide range of perspectives of any secondary principal, instructional coordinator, and science educator who met the criteria of NGSS implementation to gain a wide range of insights based on experiences on the phenomena. Electronic recruitment was used to seek voluntary participants willing to share their experiences. The selection was made for interested individuals who fit the pre-determined criteria, with consideration for sampling size. The study's practical feasibility requires acknowledgment of time and resources (Farrugia, 2019), limiting the sample size to the necessary evidence needed to answer the research questions without generating redundant data and oversaturation. Selected participants participated in the general verbal questionnaire and a face-to-face interview.

Instrumentation (Qualitative)

The development of an instrument to explore the perceptions of NGSS implementation requires identifying the themes essential for effective implementation of the science standards. Therefore, the themes are therefore necessarily aligned to the *Framework* (National Research Council, 2012), as this research-based document is the foundation of NGSS. By conducting interviews with principals, instructional coordinators, and science educators, this qualitative exploratory case study provided the opportunity to chronicle the perceptions of the journey of NGSS implementation (Shernoff et al., 2017). Unfortunately, a current instrument that measures all components of the intended research questions does not exist. Consequently, aspects from several studies and published NGSS implementation guides were consulted to design and create this investigation's instrumentation.

I crafted the original questions for the interviews after a review of components from prior research instruments used by Brunsell et al. (2014), Harris et al. (2017), and Iveland et al. (2017). Additionally, the instrument was specified to the current literature reviewed in Chapter 2 and the research questions under investigation to prevent bias in the researcher-developed questions. The designed instrument was peer-reviewed by two current secondary science teachers and revised based on their feedback to strengthen their content validity. Based on the paradigm of sensemaking theory (Schön,1983; Weick,1995) and the *Framework* (National Research Council, 2012), the questions were designed to encourage participants to provide reflective responses based on the perceptions of their experiences. The interview questions (Appendix A) are open-ended and aligned to the semi-structured interview style. As promoted by Rubin and Rubin (2012), the focus was on hearing the data and interpreting their meaning. I pilot tested the researcher-developed instrument before use in the study.

Procedures for Recruitment, Participation, and Data Collection

Recruitment, participation, and data collection for this study focused on the process of participant interviews. The semi-structured interviews were completed within a 45 to 60 minutes timeframe. Due to current COVID-19 state-wide restrictions, the interviews occurred using Zoom as a secure virtual format. The established interview protocols guided the interview experience with questions and potential follow-up questions identified. Systematic measures were taken to ensure appropriate recruitment, participant selection, data analysis, and data collection to reinforce the study's trustworthiness.

Recruitment of all participants occurred in collaborative coordination with each district's curriculum and instruction department participating in the study. Principals, instructional coordinators, and science educators were sent separate email invitations to participate. The email described the participant criteria, requirements, time commitment, and goals of the study. Interested individuals were provided with my contact information. All individuals who respond to the email were confirmed as eligible participants. All individuals who were interested in participating and meet the selection criteria were selected as participants. The targeted number of three principals, six instructional coordinators, and nine science educators from four New Mexico school districts were sought to participate. However, due to the COVID-19 pandemic, the willing participate group was smaller than anticipated.

Selected participants were sent the informed content to participate in the study electronically. The informed consent unequivocally explained the participant's obligations, timelines, time requirements, benefits of participation, risks, and how to withdraw from the study. Follow-up electronic communication were used to schedule the date and 1-hour time slot for one-on-one interviews. Great care was taken to determine a mutually beneficial time, with consideration of not interfering with the instructional day. The interviews were recorded using two digital recorders for the data collection, and files were downloaded and stored on a private, password-protected laptop computer. Interviews were then transcribed, with a copy sent to the participant for member checking. During the interviews, I took field notes to capture any reflections during interviews to monitor bias and accuracy. The field notes were stored in a locked safe for five years, with no personally identifiable participant information to maintain confidentiality. Principals, instructional coordinators, and science educators could withdraw at any time from the study before completing the interview.

Data Analysis Plan

The data collected through the interviews were analyzed to answer the research questions, aligning with sensemaking theory (Schön,1983; Weick,1995) to support the theoretical framework and the *Framework* (National Research Council, 2012) to guide the conceptual framework. A multi-stage process was used to apply provisional codes, open coding, and software analysis. The data collected from the study was first addressed by pre-coding to develop preliminary codes. Once pre-coding of the interview transcripts was established, open coding was applied to the interviews to assign codes to words or phrases (Ravitch & Carl, 2016) by participant sub-group. As Schwandt (2015) described, qualitative research can be assisted by embracing a deductive process and the traditional inductive data analysis. NVivo coding was inductively applied to safeguard accurate representation of the participant's use of language, which supported the development of patterns in the data (Ravitch & Carl, 2016) and alignment to the sensemaking theory (Schön,1983; Weick,1995). Coding memos were created to categorize the codes developed through data analysis. Principal, instructional coordinator, and science educator data was addressed separately during the initial analysis process, and then relationships were applied between them. Discrepant data was examined and reported as a component of the study. The consideration of phenomena was determined based on the data collection and examined in relation to the emerging themes. Identified themes and patterns were analyzed with the *Framework* (National Research Council, 2012) to answer the research questions through a deductive lens. Software analysis was used to verify the researcher identified categories and themes. NVivo software confirmed emerging patterns and themes through word frequency counts and coding features. Data analysis of this study necessitated the detailed review of interview transcripts to develop codes, which formulated categories, to cultivate themes used to answer the research questions under investigation (Rubin & Rubin, 2012).

Trustworthiness (Qualitative and Mixed Methods)

Assurance in the study's results was reinforced by promoting and adhering to the components of trustworthiness. As a critical component of the study, trustworthiness was addressed through meticulous consideration of the study's credibility, transferability, dependability, and confirmability. Issues related to credibility were addressed during the investigation's planning and design was continued during the study's enactment to ensure internal validity. Credibility was addressed by having three sub-groups of participants triangulating different perspectives from several vantage points (Schwandt, 2015). Members checks were used to clarify the meaning of participant perceptions, while data was sought until data saturation is reached (Ravitch & Carl, 2016). Finally, structured reflexivity was used to process possible interpretations of data through dialogic engagement with peers and research journaling.

The transferability of this investigation was initiated with the chosen study topic and was purposely considered to ensure external validity. The investigation of NGSS provides the opportunity to develop context-rich, descriptive, and applicable (Ravitch & Carl, 2016) qualitative research that is not generalizable to all contexts. Instead, the study provided a deep connection to secondary science settings, and the data collected transferred to enrich the knowledge of NGSS implementation. Variation in participant selection was achieved through the three diverse groups of stakeholders sought to partake in the interviews and the use of four distinct school districts in New Mexico for recruiting participants. The study's transferability to support constructs for science education reform was the intended goal of the study.

The study's dependability was fortified through the case study model and, therefore, triangulation of data. The review of multiple perspectives of data collection created dependable stability within the data analysis. The identified participant selection and data collection process, combined with reflexive journaling by the researcher, enabled the dependability of the integrity of the study. Audit trails were used to transparently show the process of translating the participant narratives into codes, categories, and themes (Babbie, 2017). The foundation of the research design and the methodically addressed study topic addressed the study’s dependability, validity, and overall trustworthiness.

Confirmability was established through a spiraling bias review procedure, started at the conception of the study, and continued through the final submission of the study. Explicit associations with researcher bias were reflected through reflective journaling, peer debriefing, and a thorough a continued review of current literature to confirm researcher reflexivity. As my professional background includes administrative roles and secondary science educator positions, I purposefully designed the study to take place in districts where I have not worked. The identification of any potential biases was cautiously addressed in the study design, implementation, and analysis to ensure the investigation’s confirmability.

Ethical Procedures

This study complied with all ethical considerations and expectations suggested by the Office of Sponsored Research at Walden University. Before conducting any aspect of the study, I obtained Institutional Review Board approval. Each district’s superintendent was contacted and provided with an overview of the investigation’s goals. A letter of collaboration with each district was received as an initial step before any recruitment or data collection. Principal, instructional coordinator, and science educator informed consent was obtained from all contributors who agree to participate in the study and preserved the right to withdraw from the study without consequence. Confidentiality for participant’s was protected through the strategic removal of all identifying markers for any participant. Virtual interviews were required for the participants and the researcher's safety during the COVID-19 pandemic; therefore, a secure video conferring platform was used. All data collected was securely stored in a locked safe, accessible only by me, to adhere to the investigation's trustworthiness and participant anonymity. The collected data will be destroyed through shredding upon the successful acceptance of the dissertation. No additional ethical considerations are derived, as there are no identified conflicts of interest or incentives for participation.

Summary

This chapter explained the research design and rationale for the study to investigate the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS. A case study approach was used for this qualitative exploratory study to apply data triangulation to develop a holistic view of this issue. The role of the researcher and methodology were described to support the research design. The context of participant recruitment and selection addressed the purposeful sampling approach, which was used in the study. The strategies for data collection and data analysis were presented in alignment with the research questions.

Furthermore, a detailed narrative was provided to justify the ethical procedures commissioned during the study. The issue of trustworthiness was addressed and support the study's internal and external validity, in addition to reliability and objectivity. The subsequent chapter will explain the application of the research design and the corresponding results.

Chapter 4: Results

The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. I intended to develop a deeper understanding of the perceptions of those in the field of education responsible for implementing NGSS with the possibility of gathering meaningful data on processes beneficial to enhance science instruction in the state of New Mexico. The subsequent research questions aligned with the study investigation and framed the interview protocols informing the data analysis approach.

Research Question 1: What are the perceptions of school principals, instructional coordinators, and science educators regarding the effectiveness of the strategies they have used to implement NGSS in four New Mexico school districts?

Research Question 2: What are the perceptions of school principals, instructional coordinators, and science educators regarding the barriers and challenges they have experienced in implementing NGSS in four New Mexico school districts?

This chapter is structured to present the results of the study. Descriptions of the study's setting and demographics provide the context of the study. The findings determined by analyzing data collected are described by identifying themes related to the research questions. I analyzed interview data through sensemaking to support the theoretical framework, while the *Framework* (National Research Council, 2012) guided the conceptual framework. I took measures to enhance the trustworthiness of this qualitative exploratory case study and specify the connection to the data collection, data analysis, and findings.

Setting

This study took place in New Mexico, with four school districts representing two small, one medium, and one large population of students in four geographically different locations within the state. In 2020 – 2021, the total combined student population of the four districts was 18,671. Each district serves a diverse group of students, with an average of 86.5% Hispanic students, 15.5% receiving special student services, and 81.2% classified as economically disadvantaged (NMPED, 2021). The participants included three secondary principals, one instructional coordinator, and four science educators representing sixth to 12th grades. The participants had an average of 13 years of educational experience, which ranged from 2 to 23 years. Each science educator was a regular education classroom science teacher in the secondary setting implementing NGSS. The instructional coordinator and principals were all in current leadership roles directly supporting the implementation of NGSS. The participants consisted of five women and three men.

Two science educators taught middle school science, one science educator taught middle school and high school at a combined secondary school, and one science educator taught high school. All four science educators had educational experience before their current role, including in other states, grade levels, or higher education. The principals represented one middle school, one high school, and one secondary school, with each principal reporting teaching experience before their administrative roles. The current position of the instructional coordinator included support for all secondary schools in the district where this individual was previously a science educator. Table 1 lists the pseudonyms used for participants and general information describing each participant's gender, current assignment, and educational experience.

Table 1

Participant Demographics

Name	Gender	Current grades	Years of experience in current position	Total years of experience
Educator 1	Female	7 - 8	2	12
Educator 2	Male	7 - 12	2	3
Educator 3	Male	6 - 8	3	13
Educator 4	Male	9 - 11	6	11
Principal 1	Female	6 - 8	3	13
Principal 2	Female	6 - 12	7	23
Principal 3	Female	9 - 12	4	16
Instructional coordinator 1	Female	6 - 12	5	14

Based on the current recommendations from the Centers for Diseases Control and Prevention (2020) at data collection, interviews were conducted via Zoom secure video conference to ensure the safety of participants and the researcher during the COVID-19 pandemic. I used a private home office for each interview to maintain sufficient privacy aligned with IRB requirements. The participants' locations ranged from private residences to empty school classrooms or offices, depending on their current remote learning or hybrid instructional model according to the district, county, and state guidance during the COVID-19 pandemic.

Data Collection

Data collection began after obtaining a letter of cooperation from the district leadership and securing IRB approval from Walden University (# 12-01-20-0746250). I sent email invitations to all qualifying secondary principals, instructional coordinators, and science educators through the district leadership. Participants who responded to the email invitation received a follow-up message to verify they met the study's qualifications and were provided with a digital copy of the consent form. Once participants responded with consent for participation in the study, we determined a date and time for the interview. After confirmation of a mutually agreeable time and a date was set, I provided a secure Zoom video conferencing link and password to join the interview. Two science educators, one principal, and three instructional coordinators expressed interest in participating and then declined due to changes in state educational mandates related to the COVID-19 pandemic throughout the data collection timeframe.

I conducted semi-structured interviews with eight participants using a protocol to maintain alignments to the research questions and uniformity for all interviews. The open-ended structure of the interview protocol provided a consistent process for participants to share their perspectives of NGSS implementation while also allowing flexibility for expansion and clarification of their personal experiences. I used Zoom video conferencing to conduct the interviews. All participants elected to have their video camera on during the interviews, allowing for a face-to-face virtual experience. To record audio during each interview, two independent digital recording devices were used.

Recorded audio was stored on the internal memory of the digital recorders. In alignment with IRB expectations, audio and video were not recorded in the Zoom platform. During each interview, field notes were taken to note specific events, strongly expressed ideas, and unanticipated comments.

An example of a significant statement made by Science Educator 2 was, “It kind of hurts when your first experience with NGSS is a negative evaluation when you have not had an opportunity to learn or have support.” Another example was a strongly expressed idea by Principal 2, stating, “Administrators do not need to dig into standards.” These statements exemplify noteworthy participant experiences, and I documented them in my field notes. Following each interview, I reviewed my field notes, noted nonverbal cues, documented general perspectives, and generated a summary document in the researcher log. Notations of common themes and discrepant events in the researcher log were recorded and referred to during data analysis.

Interviews had 1-hour time allotments. However, most concluded after 45 minutes. One interview required the entire hour, as the participant provided in-depth details related to their experiences and perceptions. Table 2 demonstrates the correlation between the research questions and the interview questions. Each interview was transcribed verbatim into a word document through researcher review of the audio recording and sent via email to the participant for member checking within 72 hours of the interview. Transcripts ranged from seven to 11 pages in length. One principal and the instructional coordinator made slight revisions to wording that were not documented correctly through member checking due to transmission disruptions during the video conference interviews. Those two transcripts were corrected and resent to the participants. All participants confirmed the interview transcripts reflected their experience and perceptions of NGSS implementation. All participants were thanked for their participation and will be provided with a one-page summary at the conclusion of the study. Participants were not provided with compensation.

Table 2

Correlation Between Research Questions and Interview Questions

Research question	Interview question
1. What are the perceptions of school principals, instructional coordinators, and science educators regarding the effectiveness of the strategies they have used	1. When and how were you first introduced to the Next Generation Science Standards (NGSS)? a. What was your initial reaction to NGSS? 2. Since your initial introduction, what NGSS-based professional learning have you received or participated in? a. Who provided that professional learning? b. Was the professional learning effective in supporting your learning of NGSS? 3. Based on your current understanding of NGSS, would you classify yourself as an expert, proficient, or a novice? a. What specific experiences in NGSS implementation have supported your understanding?

Research question	Interview question
to implement NGSS in four New Mexico school districts?	4. How would you describe the three-dimensional nature of NGSS to a new science teacher? 5. What strategies have you used to implement NGSS? a. Which of these strategies were effective and why? 6. What role do you believe that NGSS performance expectations should guide assessments in a science classroom? a. What does that look like for students? 7. What strategies do you use to determine if three-dimensional NGSS instruction is taking place? a. Do you think that all three dimensions of NGSS should be observed at all times in a science classroom? 8. Do you think that NGSS is useful or relevant to improving students' understanding of science and enhancing motivation? a. Can you provide an example(s)?
2. What are the perceptions of school principals, instructional coordinators, and science educators regarding the barriers and challenges they have experienced in implementing NGSS in four New Mexico school districts?	1. When and how were you first introduced to the Next Generation Science Standards (NGSS)? a. What was your initial reaction to NGSS? 2. Based on your current understanding of NGSS, would you classify yourself as an expert, proficient, or a novice? a. What would support advancing your current understanding of NGSS? 3. How would you describe the three-dimensional nature of NGSS to a new science teacher? 4. What strategies have you used to implement NGSS? a. Which of these strategies were ineffective and why? 5. What strategies do you use to determine if three-dimensional NGSS instruction is taking place? a. Do you think that all three-dimensions of NGSS should be observed at all times in a science classroom? 6. What specific challenges or barriers have you experienced in implementing NGSS? a. What would resolve these challenges and barriers? 7. That concludes all of the questions I had for this interview. Is there anything additional that you would like to add?

Data Analysis

The study applied a qualitative exploratory case study methodology to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS. To apply provisional codes, open coding, and software analysis in a systematic approach, an interval process was used. I read the interview transcripts and researcher log notes in numerous intervals to generate researcher memos. The memos documented insights that supported data analysis. Appendix B provides the synthesis of phrases from the memos used to initiate the coding process. First interval pre-coding of data from the memos assisted in the development of preliminary codes utilizing qualitative thematic analysis strategies. Then, open coding was applied during the second interval to the interviews to assign codes to words or phrases (Ravitch & Carl, 2016) by participant sub-group. Participant perceptions were considered relative to sensemaking theory (Schön,1983; Weick,1995) as the theoretical framework and the *Framework* (National Research Council, 2012) to support the study's conceptual framework. Any potential emerging theme was carefully considered throughout this process. During the third interval, NVivo 12 Mac © coding was inductively applied to safeguard accurate representation of the use of language by participants, which supported the development of themes in the data (Ravitch & Carl, 2016).

The principal, instructional coordinator, and science educator data were addressed separately during the initial memo analysis process to consider each participant group in a case study analysis. Subsequently, based on the sample group size and discrepant data of only having one instructional coordinator participate, a correlation was applied between the subgroup responses and considered holistically, as presented in Table 3. I read the transcripts and researcher logs multiple times to generate memos. The memos provided insight on connections between participant descriptions and the study's framework. I used the memos to generate pre-codes. Subsequently, open coding was used to interpret each piece of data to create codes. Similar codes were then grouped into categories. The categories were then analyzed to determine the emerging themes presented in the data. Identified themes and patterns were analyzed with the *Framework* (National Research Council, 2012) to answer the research questions through a deductive lens. NVivo 12 Mac © software verified the researcher identified categories and confirmed emerging patterns and themes through word frequency counts.

Results

The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS. The eight study participants provided detailed descriptions of their perceptions of the successes and challenges of NGSS implementation concerning the research questions. The section below documents the results of their experiences as the interpreter through the codes, categories, and emerging themes indicated in the data collected.

Research Question 1: What are the perceptions of school principals, instructional coordinators, and science educators regarding the effectiveness of the strategies they have used to implement NGSS in four New Mexico school districts?

Research Question 2: What are the perceptions of school principals, instructional coordinators, and science educators regarding the barriers and challenges they have experienced in implementing NGSS in four New Mexico school districts?

The descriptions of their understanding emerged through personal experiences and perceptions of NGSS implementation. Qualitative coding was used to index the data to make sense of participant responses and discrepant data in relation to the research questions. The codes were sorted into categories based on patterns and are represented holistically in Table 3. Participant perceptions of educational successes and challenges of NGSS implementation surfaced emergent themes. Based on the data, the four emerging themes are 1) experiencing the three dimensions of NGSS in professional learning is beneficial, 2) current science instructional materials do not fully address NGSS, 3) NGSS performance expectations are challenging to assess, and 4) scientific sensemaking supports student college and career readiness. Table 3 provides a summary of the codes, categories, and emergent themes determined from the data.

Table 3

Codes, Categories, and Emergent Themes

Codes	Categories	Emergent themes
• Connections to prior knowledge. • Continued learning experiences support classroom application. • Hands-on learning helpful. • Integration of the three dimensions of NGSS is difficult. • Job-embedded PD not provided. • More training needed. • Not enough support. • Overwhelming to learn how to teach NGSS. • Professional learning communities provide support. • Traditional teaching versus facilitating learning. • Unpacking standards for understanding.	• Application of science practices and crosscutting concepts requires support. • Experience of three-dimensional learning develops understanding. • Immersive training is beneficial. • NGSS-specific professional development.	• Experiencing the three dimensions of NGSS in professional learning is beneficial.
• Addresses content (DCIs), but not CCCs or SEPs. • Consumable materials required. • Curriculum addresses only parts of NGSS. • Finding aligned curriculum is challenging. • Instructional resources are expensive. • Instructional resources not provided in multiple languages. • Lack of available resources. • Need multiple curriculums to address all three dimensions of NGSS. • Not enough funding. • Science lab resources for hands-on learning. • Technology-based curriculum has pros and cons.	• Fully aligned standards-based science curriculum is not available. • Lack of resources to teach NGSS. • NGSS requires curriculum and lab-based resources. • Science instructional material funding is insufficient.	• Current science instructional materials do not fully address NGSS.

(table continues)

Codes	Categories	Emergent themes
• Assessments are not aligned to anchor phenomenon. • Available assessments not aligned. • Challenging to determine student mastery. • Authentic tasks. • Depth is required. • Difficult to assess all three-dimensions. • Grading open-ended tests takes longer. • Need formative assessments. • Not enough time to create quality assessments. • Performance expectations contain all three dimensions. • Premade assessments do not connect to real-world application of knowledge but are convenient. • Students not reading at grade level. • Technology-based assessment are typically multiple-choice.	• Assessing student performance based on mastery. • Lack of experience in designing three-dimensional science assessments. • Premade assessments require less time to prepare compared to writing one. • Three-dimensional assessment require more time.	• NGSS performance expectations are challenging to assess.
• Asking questions. • Claim based on evidence. • Engagement in the standards. • Hands-on investigation. • Higher-level thinking. • Not every student will attend post-secondary education. • Phenomena-based instruction. • Real-world application. • Relevant to students. • Self-directed learning environment. • Student sensemaking. • Synthesis of information. • Three-dimensional lessons.	• Inquiry-based investigation. • Conceptual understanding rather than memorization. • Prepare students for the future. • 21st century learning.	• Scientific sensemaking supports student college and career readiness.

After reviewing the research log, several themes emerged as significant. First, only Instructional Coordinator 1, Secondary Principal 2, and Science Educator 3 considered themselves within the range of proficient in their understanding of NGSS. Secondly, all participants cited concerns regarding a lack of available professional learning opportunities and insufficient planning time for educators. The following section will present the findings of the study. Data will be presented by theme, in relation to the research questions and alignment with the study's conceptual and theoretical framework. Direct quotes from the transcripts of the interviews to accurately represent participant answers to interview questions.

Theme 1: Experiencing the Three Dimensions of NGSS in Professional Learning is Beneficial

All of the interviewed participants were aware that the state of New Mexico had adopted the NGSS, and their district was mandated to implement them in K-12 science classrooms. Each participant acknowledged that the NGSS required instructional shifts in science teaching compared to previous standards and represented various effective strategies and challenges related to NGSS implementation and professional learning structures. Except for Instructional Coordinator 1, each participant expressed a need for additional professional learning opportunities to enhance their current understanding of the three dimensions of NGSS and how to implement them effectively.

Effective Professional Learning

Based on the interview responses, seven out of the eight participants expressed some effectiveness related to professional learning experiences with NGSS. However, only three participants described themselves as proficient in their understanding of NGSS and implementing NGSS-based instruction. The type and depth of NGSS-based training varied among participants. For example, Science Educator 1 was introduced to NGSS through a two-day training in which materials were presented from a teacher and student perspective that made NGSS "A little easier to grasp and not quite so daunting." The idea that experience with the standards through training supported feeling less overwhelmed was stated by most participants. On the other hand, Science Educator 3 was able to attend a full week training that provided "Hands-on activities" and opportunities to "Interact with other educators," which supported the self-identification as "Low end of proficient." According to Secondary Principal 1, the attendance of a two-day training with her teachers that had "Well-designed hands-on activities that they wanted us to work through as if we were students and they did a good job of modeling what that type of instruction would and should look like" was most helpful to build understanding. Based on school-based curriculum alignment, Secondary Principal 2 knowledgebase was "Proficient" as going through that process "With the science teachers I feel gave me a good foundation of what it's about." Noted in the responses from all the science educators and secondary principals was that training had been offered as a single event at the beginning of NGSS implementation but not as a continual process. Distinctive from the other participants, Instructional Coordinator 1 has participated in an ongoing progression of diverse NGSS training over the past several years. Based on this experience, Instructional Coordinator 1 indicated, “I am somewhere between proficient and expert because while I have some experience teaching in the classroom, most of my experience has been in the role of coordinator supporting educators, so I’m quite knowledgeable with the standards and the three dimensionalities of them.” Constant through all participant’s experiences was the distinction that immersive, inquiry-based, and ongoing professional development was most supportive to the learning process.

Challenges and Barriers to NGSS-Based Professional Learning

Contrasting most of the described effective components of professional learning was a persistent request for additional training to support an advanced understanding of how to implement NGSS. Science Educator’s 2 first introduction to NGSS when he received an email requesting teacher participation in an NGSS survey, and at that point, “I had never heard of them.” Additionally, Science Educator 2 was distress over getting “Dinged on an evaluation for not having the standards posted” even though the expectation of NGSS had never been discussed and had received “No training.” By contrast, Science Educator 4 has participated in curriculum driven NGSS training but still identifies as a “Novice” due to a continued lack of understanding of “How to implement these standards” and concern that “I don’t know if my kids can do this.” A challenge ardently made by Secondary Principal 1 indicated that before the two-day training, “They were supposed to do full implementation the following fall, but there had been no PD.” Secondary Principal 2 and Secondary Principal 3 stated that they and their science teachers had not participated in formal NGSS training. Secondary Principal 2 explained that “Getting my teachers trained would be my primary goal,” in addition to stating that “I don’t think I need to be an expert in it” as long as the teachers understand NGSS. Secondary Principal 3 has “Reviewed those standards with my teacher” but specified, “I have not participated directly in any” professional training on NGSS. According to Secondary Principal 3 to move out of the “Novice” category, they need additional “Time with the standards.” Noted in the perceptions of principals was a shared response that they did not need to be an expert in NGSS. However, their teachers did need advanced understanding. Expressed by all participants was the increased need for teachers to understand all three dimensions of NGSS and then integrate them into teaching and learning cycles. Secondary Principal 1 indicated a lack of availability of professional development by stating, “I would love to send my teachers to more of that type of PD, um, but if it’s not provided then, then, you know we’ll create it here at the building level.” Apparent in all responses was a request for additional professional learning experiences focused on hands-on inquiry learning, support understanding and integration of the three dimensions of NGSS, and ongoing support for conceptual understanding. Each interview described a lack of resources and staff at the building level to create the three-dimensional professional learning necessary to support science educators. Also evident during interviews with the science educators and secondary principals, the apprehension toward three-dimensional learning or vague understanding of the relationship of the three dimensions to NGSS.

Theme 2: Current Science Instructional Materials do not Fully Address NGSS

Distinct in the participant’s responses is the reliance on the existing curriculum to support NGSS implementation and an agreement that none of the curriculum options are fully aligned to the standards. All participants worked in districts that had adopted a new science curriculum to address NGSS implementation through instructional materials funding. Participants discussed the advantages and limitations of their adopted curriculum. The four districts each have a different primary curriculum resource implemented in diverse formats. This section will focus on the effective components and challenges with the NGSS-based curriculum as represented by the participants and not analyze the specific adopted curriculum in each district.

Instructional Supports are Provided by Science Curriculum

During interviews, all of the participants related NGSS implementation to the teaching from the adopted science curriculum. The adopted curriculum was generally viewed as constructive as it provides a baseline for instruction. Science Educator 1 focused on being “More technology-based” with the online curriculum they are utilizing. It is beneficial for students to have “Something interactive they can work with” through technology. Science Educator 3 advocated that “Having the materials makes a huge difference” on the effectiveness of the curriculum. The curriculum provided to Science Educator 3 provides resource kits, including annual consumable items, that allow for hands-on experiences with students. According to Science Educator 4, “The materials and stuff we have has really helped in implementing that because it provides a lot of notes and background information." Secondary Principal 3 affirmed that to implement a curriculum appropriately, teachers also need access to additional resources.

Regarding teachers, Secondary Principal 3 stated, "I try to trust them as professionals in that they tell me what they need and when they tell me they need something, I get it for them." Overall, the need for the curriculum was clear, and each district had adopted a resource that was at least partially meeting the needs of NGSS instruction. Most often, the participants identified their curriculum addressed the DCIs, which represent the science content, lacked materials needed to implement the SEPs, and rarely addressed the CCCs.

Challenges and Barriers to NGSS-Aligned Science Curriculum

Several challenges and barriers to the NGSS-based curriculum were described during the interviews. First, the lack of funding needed to purchase all the instructional materials and curriculum needed to implement the standards at each grade level. Second, seven out of the eight participants identified currently available curriculum that is not fully aligned to all three dimensions of all NGSS standards. As an example, although Science Educator 2 has access to an adopted curriculum, the resources are not described as valuable for instruction and therefore, it is required to "Write everything" for instructional lessons. Another challenge consists of a curriculum that does not fit the needs of the students or standards. As stated by Science Educator 4, "If there's been difficulties, I've been able to tweak it and make it better, make the adjustments, and hopefully make if better for the kids." The amount of time required for teachers to adjust or create a curriculum can hinder providing high-quality, standards-based instruction.

Secondary Principal 1 affirmed that “Looking for a well-aligned, supported curriculum was not an easy task” and that adopting one was “Not cheap.” Many participants underscored the lack of allowable science curriculums in New Mexico supported by NMPED instructional materials funding and stated that the budget provided did not cover all purchases of the full spectrum of curriculum needed for each grade level. Secondary Principal 2 advocated that “Teachers deserve their autonomy” but can create issues when teachers in a building decide to follow different curriculums. Instructional Coordinator 1 said, “We knew it was going to be human nature to revert to what we know so we chose materials that were essentially radically different than anything we’ve ever done.” Additional resources, materials, and lessons were stated to be added to all curriculums to address students’ needs or to address all three dimensions of the standards. During 3 interviews misconceptions regarding SEPs and CCCs were noted, based on missing components in the implemented curriculum.

Theme 3: NGSS Performance Expectations are Challenging to Assess

In NGSS, the performance expectation is the principal statement for each standard and communicates what students should know and do by the end of instruction on that topic. Therefore, the performance expectation specifies how and what the assessment should look like for each standard. In addition, the performance expectation is written to include all three dimensions embedded with the standard. Consequently, student assessments should also address all three dimensions of each standard. Indicated through participants’ perceptions, finding existing or designing assessments aligned to the performance expectations of NGSS can be a demanding task.

Benefits of Three-Dimensional Assessment

Identifying appreciation for the clarity provided by the NGSS performance expectations, Science Educator 1 stated, “It’s like our mission statement, this is what we need to learn, and this is why we need to know this.” Secondary Principal 1 said, “In theory, if the standards are what the state is assessing, then as long as the teachers are teaching the standards, we shouldn’t really have to worry about what’s on the state assessment because that alignment should be there organically.” Secondary Principal 1 also stated that “Assessments should be content-driven” and “Performance-based.” In a comprehensive description, Instructional Coordinator 1 indicated that science assessments should be “An authentic task that causes students to engage” and “Open-ended where they have room to synthesize where there’s not necessarily one right answer” to address the performance expectations of NGSS. Science Educators 3 and 4 indicated they preferred the online, electronic format provided by their curriculum for assessments because it was easier to grade.

Challenges and Barriers to NGSS Assessment

Science Educator 2 explained that they do not use NGSS or the performance expectations to assess students citing that it is “Difficult to get through the standards in any short amount of time.” Science Educator 3 indicated that he only uses the embedded online assessments that came with the curriculum but voice significant concern that resources cannot be edited. Science Educator 3 worried that the assessments are not always aligned to what his students can do, and editing is required for alignment. Science Educator 3 also noted that he has a large population of students with English as their second language, and the curriculum-based assessments are not translated to other languages. In addition to not recognizing the performance expectations with the standards, Science Educator 4 also stated that the assessments are multiple-choice and only assessing the content. Based on modification in standardized assessment due to COVID-19, the pilot NGSS-aligned science assessment was postponed for the past two years. Secondary Principal 1 discussed their frustration with not knowing what students will be assessed on in science and the lack of data to determine how standards-based teachers are teaching. Secondary Principal 3 repeated Secondary Principal 1's thoughts by stating, "Students need a fair chance to be assessed on what they're actually learning in the science classroom, but we haven't seen our new science assessment," indicating a lack of alignment may exist. Secondary Principal 2 discussed the importance of assessments in science but shared, "I haven't found any really good formative assessment for NGSS." Secondary Principal 3 expressed that if NGSS is performance-based and three-dimensional, then the assessments must be as well saying "We're teaching hands-on, so we should allow students to show us what they're learning, not just answer a bubble sheet about what they learned." Shifting the design and application of assessment was stipulated as a process that no participant had been specifically trained in.

Theme 4: Scientific Sensemaking Supports Student College and Career Readiness

The fourth theme emergent in the data is derived from the emphasis by all participants that NGSS supports student learning. Although not all agreed with the specific benefits, overall, everyone discussed to the application to real-world exploration and transferability to scientific skills to post-secondary settings for students. The section below outlines the perceptions of effectiveness and challenges related to the scientific sensemaking embedded within NGSS instruction.

Connections to Advancing Post-Secondary Opportunities

All participants in the study acknowledged the need to prepare students for their future, regardless of each induvial student's path in the post-secondary chapter of their lives. The diversity of options for college and career following high school was recognized as a driving force focusing on scientific skills that have transferability to numerous settings, such as communication, critical thinking, and collaboration. Participants clearly articulated the connection between NGSS and the advancement of college and career readiness skills. For example, Secondary Principal 1 suggested, "Not every student is destined for post-secondary education," however there has been a "True lack in problem solving and critical thinking" that NGSS can improve to support all students in college or their career. Many spoke to the organization of NGSS and implied that due to their strategic design, teachers would be able to more accurately implement that as their understanding increases compared to the previous science standards. Science Educator 2 said, "I think they're a better set of standards, and they lay things out in a better way." Secondary Principal 2 restated that idea by explaining that NGSS is "Easier to understand, easier to read" and "The standards are appropriate for students to be learning at that level." Another identified area of effectiveness stems from stimulating motivation through relevance and critical thinking by increasing student investigation of phenomena. As perceived by Science Educator 3, "Students are much more engaged with the hands-on, being able to formulate their ideas." Restated by Science Educator 1, "I do think it motivates them, and the real-world application is needed." The interviews often referred to the idea that high-quality instruction based on three-dimensional standards leads to student engagement. Secondary Principal 3 stated that NGSS evokes enhanced motivation for learning science by causes "Greater output, greater engagement" from students by allowing for group projects, "Physical movement" in the classroom, and the opportunity to enhance curriculum alignment. Instructional Coordinator 1 expressed that through NGSS, students will be better prepared for post-K-12 education due to the "Instructional practices that support student learning, increased student engagement from understanding the relevance, and being empowered." Overall, the participant presented thoughtful opinions about the synchronicity of NGSS and preparing students for their future. All participants gave support for NGSS's ability to enhance student achievement in 21st-century skills and classroom engagement.

Challenges and Barriers to College and Career Readiness

Grounded in concerns not yet addressed, participants shared their apprehensions on student preservation of content through the school year, gaps in the spectrum of K-12 NGSS implementation, and teacher retention. For example, Science Educator 2 stated, "I don't see the value in exposing students to the standards through the entire curriculum" because the information would be too much and get lost along the way. Based on this idea, it was also indicated that they have not been following the NGSS standards and are doing fine without them. Although Science Educator 4, agrees with NGSS having great benefits for students, concerns were voiced that until the elementary grades below implemented NGSS with fidelity, students do not reach the upper-grade band with the

"Prior knowledge" and skills necessary to be successful. Associated to Science Educator 2's statement, teachers, schools, or grade levels do not implement NGSS, which may impact the students' future science courses. Voiced by all three Secondary Principals was the concern of teacher retention and how to ensure that high-quality instruction is maintained when science teachers retire and new ones are hired. Barriers presented by logistics were framed by implementation challenges experienced during the process. Shared by all participants was a common understanding that more work is needed to ensure all students receive NGSS-based instruction as intended by the standards and required for their upcoming college or career experiences.

Connections Between the Emerging Themes, Theoretical Framework, and Conceptual Framework

The emerging themes are grounded in the data collected and relate to the study's conceptual framework. The components of the sensemaking theory (Schön,1983; Weick,1995) and the *Framework* (National Research Council, 2012) were considered concerning the emerging themes, and alignment between the three was established. Table 4 demonstrates each emerging theme and its association to the sensemaking theory (Schön,1983; Weick,1995) as the theoretical framework and the *Framework* (National Research Council, 2012) to support the study's conceptual framework.

First, the sensemaking theory (Schön,1983; Weick,1995) recognizes the initial stages of learning as identity construction and retrospection. As identified in the first emergent theme, participants gained an increased understanding of NGSS and the implementation process when allowed to construct the identity of this format of learning and apply the shifts in NGSS with retrospective reflection. This idea aligns to the *Framework* (National Research Council, 2012) description of appropriate teacher development for NGSS as a fundamental transition structure to this science instruction format. The connection between educators experiencing the three dimensions of NGSS as a learner and using the initial stages of sensemaking to conceptualize the connection to their classroom instructional practices was noticeably expressed in the data. Additionally, participants advocated that further experiential professional development would support increasing their understanding of NGSS.

Secondly, sensemaking (Schön,1983; Weick,1995) establishes that making sense is supported through the enactment of learning through socialization and the continuation of related processes. As described in the *Framework* (National Research Council, 2012), implementation of NGSS must be met with a three-dimensional curriculum, exploratory classroom experiences, and performance-based assessment. Concerns presented in the data indicated that current instructional materials do not align to NGSS and therefore are a barrier to the second layer to sensemaking during NGSS implementation and assessment of student mastery.

Finally, the learning application is described in sensemaking (Schön,1983; Weick,1995) as extracting cues and plausibility. This process is supported by the *Framework* (National Research Council, 2012) as integrating the three dimensions of NGSS, in which students experience science (SEPs) while learning science content (DCIs) and use patterns (CCCs) to determine relationships between prior knowledge and new learning. The emerging theme that scientific sensemaking supports student college and career readiness within the data links the importance of application and transferability of extracted cues and complexity of tasks to new situations through three-dimensional learning. Table 4 visualizes the connections between this study's conceptual framework, theoretical framework, and emerging themes.

Table 4

Connection Between Themes, Theoretical Framework, and Conceptual Framework

Sensemaking theory (Theoretical framework)	Emerging themes	*Framework* (Conceptual framework)
Identity construction Retrospection	Experiencing the three dimensions of NGSS in professional learning is beneficial.	Scientific and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas, and Implementation: Teacher development
Enactment Socialization Continuation	Current science instructional materials do not fully address NGSS. NGSS performance expectations are challenging to assess.	Implementation: Curriculum, instruction, and assessment
Extracted cues Plausibility	Scientific sensemaking supports student college and career readiness.	Integrating the Three Dimensions

Evidence of Trustworthiness

Foundational to the trustworthiness, a study must offer evidence of (a) credibility, (b) transferability, (c) dependability, and (d) confirmability. To ensure the trustworthiness of this study, I thoughtfully addressed components throughout the process of this study. To establish internal validity, credibility was attended to throughout the investigation's planning, design, and data collection. I strengthen the trustworthiness of this qualitative study by utilizing diverse approaches to address issues of credibility, dependability, transferability, and confirmability. I employed strategies encouraged by Rubin and Rubin (2012) in coordination with methods supported by Ravitch & Carl (2016) that directed the specific steps appropriate for this qualitative study. The subsequent subsections will explain specific strategies I employed in this study to ensure trustworthiness.

Creditability

Credibility issues were addressed during both the planning and implementation phases of this study. Credibility was supported by having three sub-groups of participants sharing perspectives from several vantage points and triangulating the data through a case study process (Schwandt, 2015). Data analysis was initially conducted separately for each participant subgroup to ensure creditability in the data was considered by role and discrepant cases considered before synthesizing data holistically. Internal validation was upheld by the participant selection process and inclusion of all willing school districts in New Mexico. Additionally, member checks safeguarded participant perceptions while data was collected until data saturation was achieved (Ravitch & Carl, 2016). Each participant reviewed the interview transcripts for accuracy, and all requested revisions were addressed before data analysis was conducted. Furthermore, I used reflexivity to analyze my judgments, practices, and beliefs to identify possible impacts to the research. I practiced reflexivity by maintaining a researcher journal to document thoughts and potential biases during the study. I also used data saturation to reinforce the creditability of the study. Data saturation was reached with the eight participants. However, as I was only able to recruit one Instructional Coordinator due to the COVID-19 pandemic, data saturation was not met in that one subgroup.

Transferability

The transferability of this investigation originated from the chosen study topic and was intentionally considered to confirm external validity. The exploration of NGSS provided the opportunity to cultivate context-rich, explanatory, and relevant (Ravitch & Carl, 2016) qualitative research that is not generalizable to all circumstances. Variation in participant selection was accomplished by interviewing three diverse stakeholders and four divergent school districts in New Mexico to recruit participants. Additionally, a wide range of experience levels and grade levels within the participant groups were represented which provided a diverse and transferable data set. Gaining insight from three different groups of stakeholders enhanced the detailed descriptions of the phenomena under investigation. This study's transferability supported the goal of exploring the contexts for science education reform in New Mexico.

Dependability

The dependability of the study was preserved through the case study model and triangulation of data among the perceptions of the three diverse groups of participants. The analysis of various perspectives of data collection crafted dependable constancy within the process of data analysis. In combination with reflexive journaling, participant selection and data collection facilitated the dependability and integrity of the study. Audit trails were used to clearly show the translation of participant narratives into codes, categories, and themes (Babbie, 2017). Utilizing semi-structured interview prompts during the interviews allowed each participant the flexibility to express their experiences and perceptions in their terms. Establishing the research design and systematically addressing the study's topic focused on the study's dependability, validity, and comprehensive trustworthiness.

Confirmability

Confirmability was addressed through an inclusive bias review, originated at the start, and was sustained through the final submission of the study. Categorical links with researcher bias were considered through reflective journaling, peer debriefing, and a continuous review of current literature to confirm researcher reflexivity. As my educational background incorporates administrative roles and secondary science educator roles, I planned the study in districts where I have not worked. The documentation of any potential biases was pragmatically addressed in the study's design, implementation, and analysis to ensure the investigation's confirmability. During data analysis, I consistently considered alternative interpretations and explanations of the data. As the study's data collection process occurred during the height of the COVID-19 pandemic, participant recruitment was impacted. Initial participant recruitment occurred when the state of New Mexico enacted a remote learning model for all schools. During this time, several possible districts and participants demonstrated interest in participation. However, shortly before starting data collection, the governor of New Mexico authorized some school districts to initiate in-person learning. The shift of instructional models caused some districts and participants to determine that time constraints would prevent their participation in the study. Therefore, the number of participating districts and participants was reduced. An outcome of this issue was the recruitment of only one instructional coordinator, which required that subgroup data be considered a discrepant event and was a consideration during data analysis. Although the study's original design was to conduct face-to-face interviews, the transition to video conference interviews due to the COVID-19 pandemic did not disrupt any form of the study's trustworthiness.

Summary

The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. Based on the participants' perceptions in this study, the implementation of NGSS in New Mexico has encompassed some instructional practices in the science classroom and several significant challenges. Four themes emerged from the data collected. Each contains components of effectiveness and barriers: 1) experiencing the three dimensions of NGSS in professional learning is beneficial of 2) current science instructional materials do not fully address NGSS, 3)

NGSS performance expectations are challenging to assess, and 4) scientific sensemaking supports student college and career readiness. The first research question under investigation explores the perceptions of school principals, instructional coordinators, and science educators regarding the effectiveness of their strategies to implement NGSS. Professional learning provided to science educators, secondary principals, and instructional coordinators that immersed them as learners of three-dimensional NGSS lessons were identified as a particularly effective strategy for implementation. An advantageous focus of the participants was access to an NGSS-based curriculum to support science instruction and implementation, even when the material is not fully aligned. Furthermore, the increased clarity provided by the NGSS standards for what student learning and assessment should look like, even if it were not yet fully being addressed, was often discussed. Finally, participants gave overwhelming support to the quality of science education NGSS will provide to the students of New Mexico and the implications for their future success based on conceptual understanding of science and enhanced 21st-century learning skills.

The second research question examined the perceptions of school principals, instructional coordinators, and science educators regarding the barriers and challenges they have experienced in implementing NGSS in four New Mexico school districts. A collective concern was the lack of professional development in New Mexico to continue advancing NGSS implementation. Most participants participated in a single event at the start of implementation and have not provided continuous support. Due to the complexity of NGSS, the absence of multiple opportunities to engage in learning was presented as a significant barrier to complete understanding and three-dimensional implementation. Another concern established by participants focused on the deficiency of a fully aligned NGSS curriculum and the shortage of funding to New Mexico schools to purchase science instructional materials for NGSS implementation. Although each school district had a newly adopted science curriculum, none was stated as being three-dimensional or fully attending to the diversity of students' needs. Significant apprehension was revealed related to the amount of time required for teachers to modify or refine existing curriculum to address the standards or a lack of understanding on how to revise curriculum to be three-dimensional. Assessment presented a substantial gap in instructional practice, as apparent hesitation about designing and implementing NGSS-based assessment existed. Distinctively evident is a need for additional professional learning related to three-dimensional and performance-based assessment. Finally, although well-defined connections to the benefits of NGSS for students were drawn, the absence of a structure to continuously provided three-dimensional professional development and support for science teacher retention was indicated as a barrier to ensuring students receive high-quality science instruction. Overall, the data collected in this study revealed an awareness of NGSS, the initial stages of implementation, and a strong need for a continuation of strategic support.

In Chapter 5, I will present the findings through an analytical discussion to expand the understanding of the results. Connections to the conceptual and theoretical framework will be expanded and the results relationship to current literature will be examined. The findings of the study will be interpreted and the limitations of the study will be presented. Implications for positive social change will be considered, and recommendations will be provided.

Chapter 5: Discussion, Conclusions, and Recommendations

Instructional shifts necessitated by NGSS require a multifaceted support system. Enhancements to content knowledge, pedagogy, and instructional design necessitate a systemic approach to facilitate students' three-dimensional teaching and learning cycles (Zangori & Pinnow, 2020). The process of implementing NGSS in secondary learning settings is not well understood and considerably underrepresented in current literature (Papadouris & Constantinou, 2017). The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts.

The conceptual framework of this study leverages the purposeful infrastructure of NGSS. The *Framework* (National Research Council, 2012) seamlessly acted as the conceptual framework by aligning participant perceptions to the three-dimensional learning components of NGSS. Sensemaking (Schön, 1983; Weick, 1995) provided the lens for how principals, instructional coordinators, and science educators perceived their personal learning experiences with NGSS implementation and therefore was the theoretical framework. The fusion of the conceptual and theoretical frameworks provided a holistic view of participant perceptions.

The findings of this study reveal that the initial stages of NGSS implementation have begun in New Mexico and are a constructive instructional shift for students. The effective strategies indicated by participants included three-dimensional and immersive professional learning experiences, access to newly adopted instructional curriculum, and increased student engagement in phenomenon-based learning. However, challenges presented by participants involved a lack of professional development opportunities, insufficiency of alignment between NGSS and adopted curriculum, absence of NGSS-based assessments that gauge student learning of performance expectations, and concern for how to sustain progress on NGSS implementation over time systemically. In this chapter, I will summarize and interpret the critical outcomes of the study and represent the limitations of the investigation. Furthermore, I will provide recommendations for future research on NGSS implementation and identify possible implications for social change as an outcome of this study.

Interpretation of the Findings

The literature reviewed for this study encompassed the need for researched-based science standards to increase student scientific literacy and a deficiency of evidence on the most appropriate process to implement NGSS. This study's findings may contribute to the current NGSS implementation on effective strategies and opportunities to address challenges in the secondary education setting. Additionally, the research findings may reinforce the need for strategic and continued support systems to implement NGSS. By identifying the perceptions of secondary educators, secondary principals, and instructional coordinators, best practices for NGSS may be identified and transferable to the next steps in implementing high-quality and research-based science standards.

The participants of this study shared their experiences, successes, and challenges during NGSS implementation. The four themes that emerged from their perceptions are three-dimensional professional learning, partially aligned NGSS curriculum, NGSS performance expectations are challenging to assess, and scientific sensemaking supports student college and career readiness. This study's findings confirm the literature reviewed in Chapter 2 by similarly establishing the complexity of NGSS implementation presents challenges to science education which are yet to be completely addressed through instructional planning, educator support, or funding (Kolonich et al., 2018; Nollmeyer & Bangert, 2017; Therrien & Benson, 2017; Woulfin & Rigby, 2017; Philip & Azevedo, 2017). The study also extends the knowledge of NGSS implementation, as no current literature existed on the transition to NGSS, specifically in New Mexico. Below, the study's two research questions are correlated with the corresponding emerging themes, interpretations of the findings, and accompanying literature.

Interpretation of Findings of RQ1

RQ1: What are the perceptions of school principals, instructional coordinators, and science educators regarding the effectiveness of the strategies they have used to implement NGSS in four New Mexico school districts?

Implementing NGSS has been an ongoing conversation in the education community since the release of the *Framework* (National Research Council, 2012) and subsequent science standards in 2013 (Tyler et al., 2020). State-driven standards implementation has caused the process has varied in the choice to adopt NGSS, the timeline for transition, and the resources provided to support the process (Achieve, 2019). The four participating districts in New Mexico each reported the initial stages of NGSS implementation and the adoption of instructional resources. The effectiveness of strategies of NGSS implementation was shared by science educators, secondary principals, and an instructional coordinator based on their perceived experiences.

Theme 1: Experiencing the Three Dimensions of NGSS in Professional Learning is Beneficial

In Chapter 4, the findings exposed that those who felt confident in their understanding of NGSS had opportunities to engage in immersive professional development, which focused on three dimensions of NGSS. The participants with multiple or multi-day professional learning experiences reported the highest level of proficiency in NGSS. Supported by the findings of Tyler et al. (2020), participants with substantial expertise in NGSS who learned NGSS by doing NGSS-based science investigations indicated amplified success with classroom implementation. Also shown within the data was secondary principals who participated in NGSS professional learning and provided advanced support systems at their schools had science educators more willing to employ implementation strategies of NGSS in their classrooms.

Additionally, large-scale professional learning experiences were critical, especially for smaller school districts, as they provide a forum for the collaboration of diverse groups. Cooperation between diverse schools supports establishing classroom communities where students investigate phenomena and focus on in-depth learning (Zangori & Pinnow, 2020). Related to both sensemaking theory (Schön, 1983; Weick, 1995) and the *Framework* (National Research Council, 2012), professional learning provides the foundation required to acquire new knowledge about the pedagogy of three-dimensional education and the specific structure of NGSS. Notable was the extensive training that Instructional Coordinator 1 participated in, although it was unclear if her advanced NGSS understanding translated into successful science classrooms. Leaders must provide sufficient training to reach a conceptual understanding for all stakeholders involved in science learning for students.

Theme 2: Current Science Instructional Materials do not Fully Address NGSS

Clearly articulated through Chapter 4 was the purposeful adoption of the curriculum in all participating districts to support NGSS implementation. The New Mexico Public Education Department provided funding in 2018 provided a statewide adoption of science instructional materials. The school districts' wide range of curricular resources provided a foundational baseline for teachers to implement NGSS. All participants had positive perceptions of the NGSS-based science curriculum and its benefits for implementation. Zangori and Pinnow (2020) explained that the NGSS-based curriculum could often be interpreted and implemented in various arrangements. Participants described variance in the use of each curriculum resource to support student learning.

Moreover, most participants explained a noticeable increase in hands-on exploration and student engagement accompanying the implementation of NGSS through their adopted curriculum. Also prominent was an escalation in technology usage, as many curriculums have an embedded online component. Although grateful for the adoption of new resources, participants were realistic regarding the advantages provided by their curriculum while also citing the deficiencies that also existed.

Theme 3: NGSS Performance Expectations are Challenging to Assess

Assessment of NGSS is an area distinctly revealed as a needed focus area. While few effective strategies were shared related to this theme, one identified area of support was gathered through the structure of NGSS. The performance expectation, which is the assessable component of NGSS, is written in the top box of the standards and identifies all three dimensions of that students and indicates how students would demonstrate proficiency. Several participants mentioned that the organized structure of NGSS performance expectations assistance their understanding of how to assess student learning.

Theme 4: Scientific Sensemaking Supports Student College and Career Readiness

The fourth theme to emerge from Chapter 4 demonstrates vast support by participants for the benefits provided to students through NGSS-based instruction. By nature, science classrooms call for a wide range of materials and activities, providing meaningful learning experiences (Zinger et al., 2020). The influence of meaningful learning purposefully designed within NGSS targets relevance, skill-based knowledge, and practical application. They were advocated by the participants for the positive impact that NGSS implementation has had and can accelerate student preparedness for post-K-12 education. As stated by multiple participants, life after high school encompasses a wide range of options for students. Regardless of the route, students will need to be prepared for all possible options. NGSS is outcome-driven, aligning with current and future careers, allowing for community connections (Tyler et al., 2020). As the need for a diverse workforce is expanding, readiness for college or career upon graduating from high school, participants voiced the increased engagement in scientific learning and acquisition of 21st century skills would serve to assist students. Concentrated within data collected in this study was the anticipation for amplified benefits as the implementation of NGSS becomes solidified and systematic throughout New Mexico.

Interpretation of Findings of RQ2

RQ2: What are the perceptions of school principals, instructional coordinators, and science educators regarding the barriers and challenges they have experienced in implementing NGSS in four New Mexico school districts?

Theme 1: Experiencing the Three Dimensions of NGSS in Professional Learning is Beneficial

The data explicitly stated that New Mexico had not provided sufficient professional knowledge to science educators or principals. Professional development should be equitable, sustained, and address the complexity of NGSS to support implementation properly (Fowler et al., 2019). Educational systems that have enacted ambitious professional learning for administrators have resulted in teachers who feel supported with the time need for planning, resources for inquiry-based learning, and experimentation with three-dimensional teaching (Tyler et al., 2020). Voiced in the participant interviews from all three subgroups was a lack of NGSS training for school leadership, contributing to the identified barriers and challenges.

Furthermore, science educators overwhelmingly requested additional support through hands-on experiences that demonstrate three-dimensional learning. Signified within responses was that participants knew enough about NGSS to see that they needed to learn more. Participants indicated that they are currently addressing one or two dimensions within classroom instruction, but not all three. Dedicated time to learn NGSS through sustained professional development is needed to advance current instructional practices to address NGSS in its entirety. In three out of the four districts, participants indicated that they do not have an expert in their district who can provide NGSS-based professional learning and therefore requires additional resources for professional development.

Theme 2: Current Science Instructional Materials do not Fully Address NGSS

As specified by the New Mexico Public Education Department (2020), “one of the most significant factors that impact student achievement is that teachers commit to implementing a guaranteed and viable curriculum to ensure no matter who teaches a given class, the curriculum will address certain essential content.” Illuminated in Chapter 4, participants did not have access to a fully aligned NGSS-based curriculum. Although all districts had newly adopted instructional materials, none fully addressed all three dimensions of NGSS. Participants felt that their resources lacked provisions for the SEPs and CCCs, which encompass two of the three dimensions of NGSS. Without access to a standards-based curriculum, teachers are required to modify lessons to include the excluded components or not address the standards completely. An additional barrier of lack of time was presented as a consequence of this issue. Extra time to design student-centered experiences was stated by participants as an unrealistic expectation based on the multi-layered and job-embedded requirements of educators. In parallel with professional learning, aligned instructional resources are necessary to address the teaching and learning reforms of NGSS (Nagle & Pecore, 2019). Full implementation of NGSS will be unlikely to occur without fully aligned NGSS resources and should be considered as a prominent barrier.

Furthermore, Chapter 4 indicated an ongoing need for additional funding to support high-quality and aligned instructional materials. As publisher-produced curriculum appears not to address all three dimensions of NGSS completely, there may be a need for educational systems to purchase multiple instructional materials to be interwoven to meet the needs of student learning in NGSS. The participants indicated a current overwhelming reliance on the provided curriculum to teach NGSS, even though it is not fully aligned. Participants struggled to address the precise components of the curriculum that were not in alignment with NGSS, which suggests a lack of understanding of the intentions of the standards and how to implement them. The funding allotment in New Mexico for the acquisition of the science curriculum was repeatedly addressed as insufficient to purchase all of the requested resources. Access to fully aligned resources should be considered as indispensable to move forward with NGSS implementation.

Theme 3: NGSS Performance Expectations are Challenging to Assess

Indicated in Chapter 4 as a main challenge, student assessment of NGSS is an area of growth needed in all four participating districts. The assessment issue is related to both Theme 1 and Theme 2, as they contribute to the barriers faced in properly assessing student learning. Concerns regarding NGSS-based assessment originate from an absence of training and a shortage of aligned resources. First, within the range of professional learning identified by participants, assessment-specific support was not acknowledged as a component. NGSS-based assessment represents a dramatic transformation from traditional fact-based assessments. Performance expectation stipulates indicators of student mastery. They encompass all three dimensions and exemplify the complexity of science learning in correlation with other standard components in NGSS. Therefore, former science assessments are not three-dimensional and cannot be used without modification to assess NGSS. Identifying or designing three-dimensional assessments requires training, support, and aligned resources (Tyler et al., 2020). Secondly, further complicating the matter is the current lack of three-dimensional teaching and learning resources, which indicates that if three-dimensional assessments were provided, students would not be prepared to demonstrate mastery in that manner. The difficultly of addressing the complexity of NGSS has led to the challenge of assessing the performance expectations. Dickinson et al. (2020) suggested that to adequately address NGSS assessment, a fully aligned professional learning system, curriculum, instructional design, and assessment must be in place. Due to the COVID-19 pandemic, disruptions in the administration of the new NGSS-aligned science assessments in New Mexico have left school districts without data to determine student proficiency over the past 2 years. Misalignments in implementation components will continue to lead to challenges in assessing students, both formative and summative until rectified.

Theme 4: Scientific Sensemaking Supports Student College and Career Readiness

Contrasting the optimism for how NGSS supports students is the notion voiced in Chapter 4 that concerns with systemic implementation have led to an unaligned system in which students are not prepared for what they are being asked to do in science classrooms. Several participants spoke of the concern that their students are not able to learn three-dimensionally as NGSS requests. This concern was not based on the students' incompetence but rather the scarcity of grade-band scaffolding leading to appropriate learning progressions for students. As educators and educational leaders understand how to build more profound core science knowledge and skills, students' college and career readiness will be enhanced (Zangori & Pinnow, 2020). As the NGSS are implemented, science learning frequently becomes more influential, stimulating, and equitable (Tyler et al., 2020). The need for an aligned system of standards-based implementation through the K-12 spectrum was addressed as a solution. Building skills and concepts over time would support the increased complexity of the inquiry-based classroom environment required by NGSS.

Limitations of the Study

As described in Chapter 1, the study was limited to the constraints of the population under investigation and the statewide NGSS implementation guidelines examined concerning the research questions, as specific science education stakeholders with experience implementation NGSS in New Mexico was the limited group of participants sought for the study. Additionally, conducting the study during the COVID-19 pandemic limited potential participant's willingness to engage in the study as the instructional model for some counties in New Mexico shifted from remote learning to hybrid in-person learning during the timeframe of data collection. Some participants withdrew their interest in participation due to time constraints presented under the shift in instructional models and the challenge of addressing the learning needs of in-person and at-home students simultaneously during a global pandemic. In following COVID-19 protocols (Centers for Diseases Control and Prevention, 2020), conducting all participant interviews virtually through the Zoom platform was also a limitation to the study because the researcher and participant were not able to make a personal connection allowed by an in-person interview and observation of non-verbal cues was restricted to the limited view of the video frame.

Recommendations

This study enriches existing research on the implementation of the NGSS. The study revealed four emerging themes from the data that provide insight on science educators, secondary principals, and instructional coordinator perceptions on the successes and challenges of NGSS implementation. My research findings may provide supplementary guidance and next steps for NGSS implementation. As identified in Chapter 3, NGSS can be an influential lever for equitable scientific learning for all students. Based on data obtained during this study, I recommend strategic modifications at the state, district, and school levels to build into sustained and equitable science educational practices. At the state level, I recommend increased opportunities for strategic science professional learning. All regions of the state should be offered diverse training options to meet the needs of all educational staff with a direct impact on science classrooms, which focuses on immersive three-dimensional experiences. Attention should be given to providing professional learning that models best practices for NGSS-based learning, including assessing the performance expectations and integrating all three dimensions during instruction. Additionally, increased funding levels should be provided to districts to support STEM resources and science curriculum at the state level.

Within school districts, leadership should gauge current levels of understanding and implementation of NGSS with science educators, principals, and instructional coordinators to determine the current baseline of instructional practices. Furthermore, school districts would benefit from ensuring the allocation of funds and resources to support the advancement of NGSS implementation as needed within each setting. Communication between district leadership and school leadership to determine each schools' specific needs would be critical in this process.

Within the context of individual schools, I advocate that science educators be provided with the resources, time, and support required to advance current levels of understanding to reach proficiency with NGSS and then continually supported with supplementary systems to maintain implementation practices. Teachers must have the curriculum and materials needed to teach three-dimensionally if they are expected to do so. Moreover, they should be provided with dedicated collaboration time with peers to review the standards, design lessons, review student work, and analyze assessment data. As teachers seek instructional leadership from their principals, school leadership should participate in the implementation to continue advancing their knowledge base to better support their staff and students.

Based on the outcomes of this study, replication of the study with a larger sample of school districts and participants would be recommended. Duplication of the study methodology and targeted subgroups of participants could further extend the base of knowledge of NGSS implementation in New Mexico and confirm the results of this study. In addition, the data collected from a replicated study could support statewide application to the recommended next steps. Also, research would be recommended in the elementary grade-band in New Mexico to correlate results to the secondary setting. Finally, as the data was collected during the COVID-19 pandemic, additional data collected on science professional development practices and instructional materials funding could support advancement in understanding NGSS implementation practices once school structures have returned to pre-pandemic status.

Implications

This study contributed to Walden University's objective of positive social change by providing a deeper understanding of science educators, secondary principals, and instructional coordinator perceptions on the implementation of NGSS. The implications for positive social change in my research study may influence the progression of NGSS implementation in science classrooms. Supporting students through high-quality science instruction is critical to foster improvements in our society. The challenges humanity faces will require innovative solutions and a society that can meet the forthcoming complexities through science and knowledge (Ames et al., 2017). Asking students to model the roles of scientists and engineers in classrooms supports application to real-world careers and aids in developing conceptual understanding through critical thinking (Huff, 2016,) and indicates the need for an inquiry-based instructional approach. Based on the results of this study, enacting the shift required by NGSS must be met with purposeful assistance for those responsible for carrying out implementation. Implicated within the current literature, NGSS implementation is a process that requires a network of progressive, sustained, and strategic support. This study supports the understanding that gaps in fundamental structures necessary for NGSS implementation result in science educators' who experience challenges in enacting three-dimensional teaching and learning in their classrooms. Without the proper knowledge or resources to successfully achieve standards-based instruction, successful NGSS implementation will be inconsistent.

While most current research focuses on the results experienced in early implementation states and at the elementary grade-band, this study provides insight on NGSS implementation at the secondary grade-band and in a non-early implementation state. As stated in the *Framework* (National Research Council, 2012*),* NGSS is intended to guide the modernization of K-12 science education by transforming science classrooms into engaging experience-based conceptual learning environments. According to Windschitl and Stroupe (2017), established formats of standards implementation will not be sufficient for NGSS. They, therefore, will create an inequitable process throughout the United States based on available resources in each state. The contrast in implementation practices between states with different funding practices directly affects science classrooms and, therefore, students. Cultivating high-quality three-dimensional for science students relies on the effectiveness of programs that support the implementation of NGSS.

Consequently, there was a need to understand the current implementation practices in New Mexico to determine the next steps in meeting the demands of the

NGSS. As implicated through the data collected in this study, further leadership and funding must address the current gaps in practice. Conceptual understanding of the three dimensions of NGSS for educators must be firmly in place before accomplishing this learning format with students. A deliberate emphasis on professional learning for all responsible implementation and increased funding to purchase resources required to address NGSS could directly and profoundly impact student learning (Ersozlu, 2016).

As the global workforce continually changes, K-12 education needs to adjust the focus from memorizing to the constructivist-based acquisition of skills and 21st-century competencies (Barak, 2017). To prepare students for the workforce, sensemaking, as noted by Weick (1995) and Schön (1983), is relevant to science leadership, science educators, and science students. Experienced-based learning in which participants make meaning from exploration supports adult learning models and well and student learning structures and therefore provides considerate implications for all science stakeholders. Enhanced implementation of NGSS could advance positive social change by enriching 21st-century thinking skills in addition to expanding conceptual understanding of the natural world (Bautista et al., 2018). Increasing scientific literacy through experience and relevance can ultimately improve student achievement within the K-12 spectrum and beyond.

Conclusion

Within the current transitional state of science education, there is a need to understand the essential components leading to the successful implementation of NGSS. The purpose of this qualitative exploratory case study was to explore the perceptions of principals, instructional coordinators, and science educators on the implementation of NGSS in four New Mexico school districts. Through this investigation, the insight gained indicated that the full implementation of NGSS would require innovative professional learning opportunities, advanced understanding of three-dimensional teaching and learning, improved availability of curricular resources, and a continued emphasis on scientific sensemaking. Although addressing the complexities of NGSS has not yet been entirely addressed, significant progress has been made within individual school districts in New Mexico to evolve science instruction.

The transition to NGSS was initiated by a wide-ranging consensus on the need for science reform. A growing STEM-based global economy requires increased science skills and problem-solving ability to advance progressively. As NGSS embodies a far departure from traditional science instruction, the need for an overall structural system is unmistakable. A systemic change must be originated by those responsible for decision-making and encompass deep levels of understanding.

The vision of equitable science education advocated by the *Framework* (National Research Council, 2012) and the philosophy that all students can achieve a high level of scientific understanding must be met by structured support explicitly in all science classrooms. Subsequently, the data collected in this study can be used to better understand the depth of NGSS knowledge and implementation strategies currently in place. Increased understanding is a critical step in generating sustainable guidance for advancing three-dimensional instruction. Emphasis on the precise successes and challenges for NGSS implementation provided in this study is vital to guide the transitioning science instruction to increase student achievement and therefore induce positive social change. Meeting the challenges of future generations must be addressed through a well-informed society using science and engineering to advance our technological capabilities. As indicated by the participants in this study, NGSS is one component of the K-12 educational system that, when entirely in place, will provide innovative instruction to better prepare students for the future.

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Appendix A: Interview Prompts

Interview Introduction:

- Introduction and review of the consent form.
- Assurance of confidentiality and review of purpose of data collection.
- Explanation that the interview will be recorded with an electronic device and field notes will be taken.

Background Information Questions:

1. What is your current role in the field of education?
    a. Principal, instructional specialist, or science educator?
2. How many years have you been in your current role?
3. What grade(s) do you currently work with?
4. What is your prior teaching experience, including grade level(s) and content(s) prior to your current position?

Interview Questions:

1. When and how were you first introduced to the Next Generation Science Standards (NGSS)?
    a. What was your initial reaction to NGSS?
2. Since your initial introduction, what NGSS-based professional learning have you received or participated in?
    a. Who provided that professional learning?
    b. Was the professional learning effective in supporting your learning of NGSS?
3. Based on your current understanding of NGSS, would you classify yourself as an expert, proficient, or a novice?
    a. What specific experiences in NGSS implementation have supported your understanding?
    b. What would support advancing your current understanding of NGSS?
4. How would you describe the three-dimensional nature of NGSS to a new science teacher?
5. What strategies have you used to implement NGSS?
    a. Which of these strategies were effective and why?
    b. Which of these strategies were ineffective and why?
6. What role do you believe that NGSS performance expectations should guide assessments in a science classroom?
    a. What does that look like for students?
7. What strategies do you use to determine if three-dimensional NGSS instruction is taking place?
    a. Do you think that all three dimensions of NGSS should be observed at all times in a science classroom?

8. Do you think that NGSS is useful or relevant to improving students' understanding of science and enhancing motivation?
    a. Can you provide an example(s)?
9. What specific challenges or barriers have you experienced in implementing NGSS?
    a. What would resolve these challenges and barriers?
10. That concludes all of the questions I had for this interview. Is there anything addition that you would like to add?

Thank you for taking the time to provide your insight on this topic. As the instructional leader of your school, gaining your perspective helps me to better under the issues related to NGSS implementation in New Mexico. It was wonderful to speak with you today. If you have any questions or comments, please feel free to use my contact information provided on the consent form to follow-up with me. Have a wonderful day.

Appendix B: Initial Memos by Subgroup

Initial coding memos

Interview question	Educator memos	Principal memos	Instructional coordinator memos
1	Standards. NGSS. Much Needed Improvement. Inquiry. Content. I had never head of them. I did not teach these standards last year. Transitioning. Training. Hands-on material. Not that different than before. Don’t know if kids can do this.	Content expertise. Trying to lay the groundwork. Need to educate myself. Adequately support the team. Intimidating. Best instructional practices. NMPED could have done better with the rollout. Apprehensive. Standards-based curriculum. NMPED did not have answers. Figure out how to make this work. Needed a more intentional roll out. Education myself to support my team through the transition. Full implementation expected with no PD. Observe teachers for implementation. School generated curriculum map. Overwhelming for teachers. A lot of standards to cover. Really hard if you don’t get a good curriculum. Curriculums fool you into thinking their covering everything. Struggle to find the right resources.	Training. Given all of the curriculum. NGSS is radically different, much needed, exciting, and relevant to students.

(table continues)

Interview question	Educator memos	Principal memos	Instructional coordinator memos
2	Training. It was easier to grasp. Wasn't quite so daunting. Let's do this step-by-step. Very informative. Took a lot of anxiety away. Project-based learning. Phenomena and sparks to hook the kids to investigation. NGSS-aligned. Anchoring phenomenon. Getting the kids to be more involved and take ownership of their learning. Went away from the traditional memorization. Interactive and hands-on. Gave me a guideline. Bad evaluation is what introduced me to the existence of the standards. Isolation. Overwhelming.	Two-day NMPED training. Wanted good curriculum PD. Learning to teach through discovery. Well-designed hands-on activities. Good job of modeling what that type of instruction should look like. Priorities. Finding well-aligned curriculum is not an easy task. Instructional materials were not cheap. Unpacking. Cross cutting concepts. Challenging instructionally. Depth of understanding. Need for professional development. Gauging student performance. No guidance on content for assessment. Frustrating. Hard to make aligned decisions. Not participated in any PD. Changed order of high school courses. Teachers needed a bigger consortium of colleagues to consult. Lack of funding. Strategic planning required. Additional support. Misalignment of curriculum. Administrator professional learning.	Training. Instructional materials kits. UT Dana Center one-year training. Understanding the *Framework*. Looking at the three-dimensions and how they are intertwined. NSTA training. Webinars. Reading articles. Interactive training where you are emersed in the standards.

(table continues)

Interview question	Educator memos	Principal memos	Instructional coordinator memos
3	Novice. A lot to process. The real-world application is needed. Most students won't engage. How can I implement these standards? Need to shadow an expert teacher and share strategies. Miss twenty to thirty percent of them. Need to learn how to actually implement a standard. Need more time to hit all standards. Writing content towards standards instead of bending content towards standards. Low-end proficient. Having the materials makes a huge difference. Need more hands-on training.	Still in our infancy of understanding. Not teaching to the depth that NGSS is asking for. Need direction from NMPED. Proficient. Curriculum alignment gave a good foundation. Getting my teachers trained is the primary goal. FOSS. Beyond Textbooks. Not comfortable with the alignment of NGSS. I do not need to be an expert. Novice. I don't work with the standards. Need to spend more time with the standards.	Most experience is in the role of a supporting. Knowledgeable with the standards and three-dimensionality. Planning and co-teaching with current teachers has not been easy. How to assess the three-dimensions is a piece that is still hanging out there. Some states are eight years in implementing the NGSS and we still don't have a full picture of assessment.
4	Let's jump in and see where we go from here. Focus on the core ideas. Start with the disciplinary core ideas. Crossing cutting concepts make the connections. Build to include hands-on. Questions. Tie together their thinking. Did not get the far with these other than knowing they exist. Practices are applicable to the standards. Crossing cutting concepts is how it applies to other subject areas. More technology based. Simulations. Meets the real world.	I don't specifically know three dimensional. Exploration of naturally occurring phenomena. Derive meaning through experience. Teacher as facilitators. Curriculum alignment was effective. Teachers leaving can result in a gaping hole. Each teacher has their own strategies. Teaching is not the same as it was. Worksheets. Digital notebook.	Science and Engineering Practices. Habits of mind. Thinking like a scientist or engineer. DCIs are the content, discrete facts. Overarching concepts. Making science relevant.

(table continues)

Interview question	Educator memos	Principal memos	Instructional coordinator memos
5	STEMscopes platform is NGSS-based. Workbook. Smart board. NGSS is great because it shows you the connections. Isn't any professional development. Rough timetable. Flexible. Middle school was already using NGSS, I was not. Design their own project. Never enough time. FOSS kits have an online component with assessments. Socratic method. Asking a lot of questions. Asking kids to explain what's going on. Draw from their previous experiences. Anchoring phenomenon. Summit Learning is helpful.	I tried to educate myself. Still have things I need to learn to support my staff. Quality professional development is top priority. Foundational understanding of NGSS. Classroom implementation. Designated PLC time. Backwards planning. Looking at assessment data. Lab materials. What supplies are needed? Anticipate where students might struggle. Exploration. I would love to send my teachers to more PD, but if it is not provided, then we will create it at the building level. Need to know each person and how best to support them. Different levels of trying to help people become competent. I rely heavily on my science teachers. Trust teachers as professions. I get them what they ask for. I'm more likely to be found in a classroom than in my office. Observe the classroom and then have a conversation.	Spent a year with the UT Dana Center facilitators. Shift to three-dimensional science teaching. Teacher leaders. Evidence statements. Instructional materials. EQUIP rubric. Implementation team. Human nature to revert to what we know so we chose materials that were essentially radically different than anything we've ever done. Team came together monthly. Change in thinking and behavior. Fidelity. Vulnerability. Peers. Feedback. Engaging students. Academic language. Deconstructing the standards was most effective. Classroom observations did not have a positive impact.

(table continues)

Interview question	Educator memos	Principal memos	Instructional coordinator memos
6	Standardized test questions. Assuming assessments are standards-based. Assessments already built in. Electronic. Self-directed learning environment. Objectives. Learning goals. Teach too many science classes. Build everything backwards. Understanding of basic phenomenon. Difficult to get through a standard in a short amount of time. Cumulative so basic skills are continually refreshed. Quantify math. NGSS guides what we need to learn and why we need to know this. Online program. Interactive. Formulate their own ideas and questions. Challenging to address second language learners.	We don't teach to the test. We are working towards across content and understanding and applying backwards design. Assessments should be content driven. Performance-based. Rubrics. Student demonstration. Paper-pencil assessments. Critical thinking. Problem solving. Multiple choice is easier to grade. Value is in teaching to depth versus breath. Selectively abandon content if needed. Need formative assessments. Haven't found any good NGSS formative assessments. Prefer online components. Students need a fair chance to be assessed on what they're actually learning. We haven't seen the new science assessment. Teachers are covering the curriculum and the content to the best of their ability. We need to study the standards to see how often they're tested and what the questions are asking.	Performance expectations are the assessable part of the standards. Beginning with the end in mind. Authentic task that causes students to engage. Real world. Open-ended questions where they have room to synthesize. Not one right answer. Make a claim and provide evidence.

(table continues)

Interview question	Educator memos	Principal memos	Instructional coordinator memos
7	Inquiry. Argument. Higher-level thinking. Difficult some days. Hope to have it all together someday, but now it's segmented. Paying attention. Test scores aren't everything. They can talk through it, they can draw it, but they don't perform on a test. Explore on their own. Depth is required by certain standards. Marco scale phenomenon. Not able to fully address all of it. Advantage of writing. Claim. Understanding relationships. Seeing connections. Anchor phenomenon. Crossing cutting concepts. Disciplinary core ideas. Models.	Student friendly language. Learning cycle. Amount of teacher talk versus the amount of student talk. Dialog and discourse. Multiple modalities. Technology. Professional development. Teachers learning and teaching NGSS at the same time. Performing experiments. My teachers know what is in the curriculum. Look for the standard being addressed. Lesson plans. Laying the groundwork. Engagement in the standards. Ask probing questions. Teaching style.	Students have to be doing the thinking. Working in small groups. Figuring out some anchor phenomenon. Scientific method should not be posted.
8	More engaged with hands-on. Formulate their ideas. Experiments. Better set of standards. NGSS lays things out in a better way. Don't see the value of exposing students to standards through the entire curriculum. Motivation. Doesn't make sense to students or teachers. Curriculum should be segmented. Implementation. No way my kids can do this. Prior knowledge. Cross cutting concepts. Problem solving.	Lack of problem solving and critical thinking. More extra-curricular activities. Sustainable program. Not every student in destined for post-secondary education. NGSS is lined out, easier to understand, and easier to read. Enhancing student motivation. Letting kids get up and move around the classroom is beneficial. Greater output from students.	Instructional practices that support student learning. Increase student engagement. Relevance. Empowered.

(table continues)

Interview question	Educator memos	Principal memos	Instructional coordinator memos
9	More time needed to develop plans. Not enough time. Most kids don't read at grade level. Language barriers. Many kids have not got science in elementary school. Trying to have student formulate a clear idea. Not enough instructional materials. Anchor phenomenon. Core ideas. Difficult. Student interest a challenge. Not able to address all standards. Projects. Difficult student behavior. Check data. Interactive. It will make sense. Don't know anything about the standards. Doing pretty well without standards. Application. Usefulness. Need training. Redevelopment of curriculum is excruciating. Guidelines. Framework to build on.	Infant phase of understanding. Challenge to continue to grow teachers. PLCs. Confidence to deliver content. Curriculum that was adopted in very effective. Lab notebook. Needed digital support resources. Largest barrier is teachers not actually understanding. Teachers deserve autonomy. Student success doesn't come from great test scores. Difficult to do group projects. Money is always a barrier. No curriculum truly aligned to NGSS. Teachers who are three to five years away from retirement.	Let go of some of the control and power. Empower student to take ownership of learning. Marked down on evaluation because it looks like I don't have control of the classroom. Implementation costs a lot of money. Is the district going to provide the resources needed to teach NGSS? Look-fors document. Presented to administrators. Didn't 100% alleviate the fears that teachers have over evaluation. Walk-throughs. Just start with the resources we have.
10	Enjoying NGSS. More structure. Would benefit from more training. Need understanding on how to teach three-dimensionally. Could be doing better. No trainings available. No support from the district. Other programs have a lot of support. Need backbone professional learning.	Need to do some more homework. Everything cannot be hands-on. I trust my teachers. New science teachers will need training. Need more direction. More PD. More support. One principal has a lot of standards to understand. There is a lot of information.	Trilled we adopted NGSS. Exciting time to be a science teacher.