1-12-2024

Elementary Teachers' Preparedness to Teach Three-Dimensional Standards in the United Arab Emirates

Zoya Houjeiri
Walden University

Walden University

College of Education and Human Sciences

This is to certify that the doctoral study by

Zoya Houjeiri

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee
Dr. Kristy Motte, Committee Chairperson, Education Faculty
Dr. Jamie Jones, Committee Member, Education Faculty

Chief Academic Officer and Provost
Sue Subocz, Ph.D.

Walden University
2024

Abstract

Elementary Teachers' Preparedness to Teach Three-Dimensional Standards in the United Arab Emirates

by

Zoya Houjeiri

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Education

Curriculum, Instruction, and Assessment

Walden University

[February] 2024

Abstract

Next Generation Science Standards (NGSS) were developed by 26 lead states with NSTA, AAAS, NRC, and Achieve in 2013 to provide a new vision for the teaching of science in U.S. schools. Teachers' applications have been mainly concentrated on efforts to align the current practices with the standards. Elementary science teachers need to use instructional practices that integrate the three dimensions: Science and Engineering Practices, Disciplinary Core Ideas, and Cross Cutting Concepts to successfully teach NGSS. The purpose of this exploratory qualitative study was to better understand how elementary teachers use pedagogical content knowledge and curricular knowledge to choose and implement instructional practices that integrate the three dimensions of NGSS when teaching science at American private schools in the United Arab Emirates (UAE). Interviews were conducted with 10 teachers who worked as elementary science teachers at American private schools in the UAE. Classroom observations and lesson plans examinations were used to triangulate data. There were multiple coding cycles with codes derived from the two research questions. NVivo was used to categorize data and generate four themes. Findings showed that participants' views were aligned with the NGSS reforms and that they had used more inquiry-based, student-centered instructional practices. However, participants did not deliver three-dimensional instruction due to a disconnect between their perceptions and the requirements of the standards. This study supports positive change by providing knowledge on how teachers implement the three dimensions of NGSS. Stakeholders may be able to use the study findings to determine what training and professional development courses are needed and to construct better policies pertaining to the quality of teaching materials.

Elementary Teachers' Preparedness to Teach Three-Dimensional Standards in the United Arab Emirates

by

Zoya Houjeiri

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Education

Curriculum, Instruction, and Assessment

Walden University

[February] 2024

Dedication

I dedicate this work to my husband, Ayham, and my son, Azam. You are the shining lighthouse in my darkest days. I would never have been able to finish this journey without your support and love.

Acknowledgements

I am forever grateful to my family for encouraging me to finish this doctoral journey. With all my struggles, they have been the driving force to help me through the obstacles that life has placed. I want to thank my dad, Essa, and my mom, Wedad, for being there for every milestone in my life. You are my idols. I want to thank my sisters, Souad, Tania, and Soha, for showing me the true meaning of love and family connection. I want to thank my partner Ayham for the support he provided along the way and for being my anchor when things got rough. To my son Azam – I love you; you are the blessing of my life. To Nadia and Nasouh, thank you for your support and encouragement throughout these years.

I am very thankful to Dr. Kristy Motte, whose professionalism, dedication, and assistance made this dream come true. I am also grateful to Dr. Jamie Jones for the hard work and mentoring that helped me achieve a high study quality.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction to the Study

The need to prepare students for a competitive job market is a global problem. School personnel should be able to provide students with the necessary proficiencies and knowledge required to succeed in college and careers (National Research Council [NRC], 2015). New methods of teaching that can prepare students for future careers influenced by technology are in high demand in the United States amid increasing visibility of modern science, technology, engineering, and mathematics (STEM) careers (Christian et al., 2021; Harris et al., 2017). The advancements in science and technology have emphasized the need to create new standards for science in the United States (NRC, 2012). The Next Generation Science Standards (NGSS) are a set of standards emphasizing the role of science at the school level to orient students towards STEM-related jobs and to help supporting the national and global economy (Christian et al., 2021; Hoeg & Bencze, 2017). NGSS can transform science education in the classroom to become more STEM-oriented. However, teachers' readiness to implement NGSS is in question as the standards call for substantial change from conventional science teaching.

NGSS are three-dimensional standards that intertwine three dimensions: Disciplinary Core Ideas (DCIs), Science and Engineering Practices (SEPs), and Crosscutting Concepts (CCCs) (NGSS Lead States, 2013a). Achieve, National Science Teachers Association (NSTA), National Research Council (NRC) and American Association for the Advancements of Science (AAAS) released the *Framework for K–12 Science Education* in 2010 and used it as a basis for NGSS (NGSS Lead States, 2013b). The updates and advancements in the areas of science and science education triggered the initiative to revise the 15-years old outdated standards and create a novice framework that can cater to the revolution in the science and engineering domains (NRC, 2012). Forty-four states, which represent 71% of U.S. students, have standards influenced by the *Framework for K–12 Science Education* and NGSS (NSTA, 2014a). As of November 2021, 20 states have fully adopted the standards, and 24 additional states are using the *Framework for K–12 Science Education* to revise their state standards (NSTA, 2014a).

Kang et al. (2019) explained that adopting the NGSS requires significant instructional shifts in teachers' practices in the science classroom. Teachers should not only have content knowledge in the domains of science but also be capable of recognizing and implementing authentic practices within the field (NRC, 2012). Teachers are requested to change the methods they use to teach science to cater to inquiry and engineering with equity. Teachers need to revamp their teaching practices to transform their classrooms from the current status quo, where students learn about science, to real-life encounters that actively immerse students in authentic situations where they make sense of the natural world (Lowell et al., 2021; Nollmeyer & Bangert, 2017).

Although many teachers view the new standards as essential, they often struggle with the implementation process (Haag & Megowan, 2015; Merritt et al., 2018; Plumley, 2019). Teachers' preparedness to teach the standards is in focus, with the NGSS standards requiring the reformation of teaching practices to match the three-dimensional nature of the performance expectations (NSTA, 2014b). Teachers, especially in elementary grades, struggle with integrating STEM and engineering practices as the engineering design process was added to science education with the NGSS (Christian et al., 2021). It is essential to observe how teachers translate the knowledge of the three dimensions into instructional practices that can be used in the classroom to teach three-dimensional instructions (Hanuscin & Zangori, 2016). This knowledge could help stakeholders in understanding what teachers need to prepare and execute lesson plans to teach NGSS and to create literate 21st-century students who may be more motivated in STEM fields.

I begin Chapter 1 by presenting background information on the problem, focusing on both its local and global manifestation. I state the problem then explain the purpose of the study. The chapter also includes the research questions (RQs) and an explanation of the conceptual framework I used. Chapter 1 includes definitions of key terms and discussion of the assumptions, scope and delimitations, limitations, and significance of the study.

Background

The Knowledge and Human Development Authority (KHDA) founded the Dubai School Inspection Bureau in response to a decision by the Executive Council of the Government of Dubai in 2007 (KHDA, 2016). The Bureau provides a comprehensive overview of the achievements and academic standards of every private school in Dubai through annual inspections (KHDA, 2016). Its primary mission is to ensure that private schools follow international programs and deliver high-quality education to students (Special Report: Education, 2012). Bureau staff inspect the use of international standards at various curriculum private schools across Dubai. In 2014, Sheikh Mohammad Bin Rashid Al Maktoum, the ruler of Dubai, released the UAE National Agenda and Vision 2021. Al Maktoum (2014) has depicted the UAE as a "first rate-education" nation that seeks "ambitious educational targets" (p. 23). The UAE National Agenda also shows research, technology, innovation, and science as the foundations of a growing and competitive economy (Al Maktoum, 2014). KHDA (2017) released the UAE National Agenda Parameter to determine private schools' improvement in attaining the National Agenda Goals 2015. The National Agenda Parameter mandates that schools participate annually in external benchmarking assessments to track their progress (KHDA, 2017). The NAP proposes that private schools across the United Arab Emirates (UAE) need to follow recognized international standards that align with their taught curriculum and to assess the progress of students in these standards (KHDA, 2016).

In line with the Dubai School Inspection Bureau guidelines and to fulfill the obligations of the UAE National Agenda Parameter, leaders of American schools in the country have needed to adopt modern and recognized American standards in core subjects. All American private schools have adopted the NGSS. NGSS standards provide a coherent methodology for teaching the science, engineering, and technology needed for the 21st century (NRC, 2012). NGSS standards also fulfill the UAE 2021 National Agenda Vision, which promotes innovation and engineering within education. Although not mandatory in the framework, adopting NGSS is seen in the UAE as an essential step to achieve the requirements of KHDA (KHDA, 2015).

Similar to the focus on the science, engineering and technology in the UAE, the US was focusing on STEM in education. U.S. students' achievement in sciences and mathematics continued to lag compared to their international peers in international and national assessments, and, accordingly, very few students major in STEM fields (NGSS

Lead States, 2013a). The U.S. is suffering from a major shortage in the STEM workforce (Han & Kelley, 2022). Governments, educators, and business groups agree that STEM is an essential linchpin for a stable economy and is the gateway for higher-paying jobs (Sawchuk, 2018). The need for more students who major in STEM careers necessitated new science standards that could promote students' curiosity towards STEM and improve their international science attainment to compete globally. The *Framework for K–12 Science Education* was developed in 2011 to propose a new vision for teaching science at kindergarten through Grade 12 (K–12) levels that integrates teaching engineering with science to improve student motivation and enrollment in STEM fields. Achieve, NSTA, NRC, AAAS, and 26 Lead State Partners developed the NGSS after finalizing the *Framework for K–12 Science Education* to mirror the vision represented within the framework and to call for changes in science education at K–12 levels.

NGSS substitutes the previous standards with performance expectations that integrate STEM and use DCIs, CCCs, and SEPs to shift the focus away from content-driven instructions. NGSS standards require teachers to shift their teaching paradigm by placing inquiry into SEPs. NGSS standards provide students with the chance to learn science through doing science, introducing CCC that bridge the various disciplines of science and focusing on DCIs that replace the broad content students used to memorize (Nollmeyer & Bangert, 2017). These standards, when properly implemented, will help students think and act like scientists, creating science-literate citizens for the 21st century (Bielik et al., 2022; NRC, 2012).

Teaching NGSS requires changes in teachers' approaches to address science instruction in the classrooms. NGSS Lead States (2013a) requires teachers to utilize the best educational practices and use their professional expertise to make informed decisions on implementing the standards in the best way. NSTA (2014b) indicated that implementing NGSS requires significant changes in instruction, curriculum, and assessments. However, teachers have expressed concerns about how to implement NGSS (Harris et al., 2017). They generally feel that they are not prepared to teach science (Plumley, 2019). Addressing these concerns are essential to achieve the vision and requirements of NGSS.

Although many teachers agree that the NGSS are robust standards that will improve students' learning, they still often struggle to implement the standards (Harris et al., 2017). Science teachers have "difficulties understanding the NGSS and were unclear on implementing the new standards because they lacked prior experience" (Bielek et al., 2022, p. 422). Teachers lack the knowledge to integrate NGSS into the educational system and often grapple with changing the curricula to meet the NGSS standards (Harris et al., 2017). Moreover, many teachers do not view the three dimensions equally, with the result that they usually spend more time on SEPs and misalign their practices to meet NGSS requirements (Castronova & Chernobilsky, 2020).

It was essential to explore how well elementary science teachers can choose practices that teach NGSS to better understand the implementation process of the standards in the UAE. Teachers who implement three-dimensional instructional practices may help stakeholders understand how to integrate pedagogical content knowledge

(PCK) with curricular knowledge to choose successful practices that teach the three-dimensional standards. This study may assist stakeholders in identifying what teachers perceive as barriers to proper implementation. The study may provide insight on professional development schemes that can potentially help teachers to implement the standards in an appropriate manner. Adequately implementing the standards may increase students' achievement and success.

Problem Statement

The problem was that it was unknown how elementary teachers use PCK and curricular knowledge to implement instructional practices that integrate the three dimensions of the NGSS. Aligning instruction is not sufficient as NGSS standards designate a new vision for teaching science through incorporating three dimensions: SEPs, CCCs, and DCIs (NGSS Lead States, 2013c). Teachers' application of the standards has been mainly concentrated on the realignment of teaching strategies or efforts to reflect NGSS (Lowell et al., 2021; Windschitl & Stroupe, 2017). Applying the standards requires teachers to undertake considerable changes to instruction and assessment in the classroom (National Academies of Sciences, Engineering, and Medicine, 2015). To accomplish the requirements of NGSS, teachers need to develop instruction, tasks, and assessments that reveal students' proficiency of the three dimensions (Penuel et al., 2015). Science teachers at the target school also seemed to lack the necessary knowledge and understanding of how they can teach three-dimensional instructions required by the NGSS, according to the head of the science department.

Teachers might have aligned their teaching practices to create more student-centered classrooms, yet they are still disconnected from the alignment and requirements of NGSS (Kawasaki & Sandoval, 2020). The current teaching methods used by science teachers do not fulfill the requirements of NGSS, which affects teachers' readiness to teach the standards (Haag & Megowan, 2015). NGSS requires students to acquire authentic knowledge and skills by the continuous use of what is learned to construct explanations or solve problems, but most classroom teachers still use teaching methods that focus on delivering concepts and provide only scattered opportunities for application. Elementary teachers find implementing the change difficult and challenging as they do not have access to curriculum material that aligns with NGSS (Lowell & McGowan, 2022; Penuel et al., 2015). Elementary teachers struggle in incorporating inquiry due to their lack of background knowledge (Kang et al., 2019). Alternatively, most science teachers at the target schools still focused heavily on teaching content by realigning the content of existing lessons from textbooks to the DCIs of NGSS and teaching the CCCs and SEPs separately as disconnected topics, according to the head of the science department.

The need for this study was substantiated by the call for further research on teachers' understanding of the three-dimensional standards and how they interpret this understanding into planning and instructional practices (Fulmer et al. 2018; Hanuscin & Zangori, 2016). Lilly et al. (2022) called for additional investigation on how teachers' knowledge affects their support of the practices to create a holistic picture of how and why elementary teachers implement NGSS curricula. This study contributed to the body of knowledge that addresses teachers' implementation of NGSS by providing a comprehensive understanding of how well teachers can use their knowledge to implement three-dimensional instructional practices that teach the NGSS standards. I examined the links between PCK, curricular knowledge, and the choice of instructional practices for teaching the three dimensions of NGSS. The results of this study highlighted the successful practices teachers use when implementing NGSS and what is required to develop their NGSS teaching.

Purpose of the Study

The purpose of this exploratory qualitative case study was to better understand how elementary teachers use PCK and curricular knowledge to implement instructional practices that integrate the three dimensions of NGSS when teaching science at American private schools in the UAE. The results of this study may improve understanding of how well teachers can choose and implement teaching practices that integrate the three dimensions of NGSS. The study may also clarify how teachers' choice of practices provides support or becomes a barrier to teaching the three dimensions at private American schools setting in the UAE. Elementary science teachers who were interviewed and observed in real classroom settings were the unit of analysis.

Research Questions

RQ1: How do elementary teachers implement instructional practices that integrate the three dimensions when teaching NGSS at American private schools in the UAE?

RQ2: How do elementary teachers integrate their PCK and curricular knowledge when implementing instructional practices that teach the three-dimensional content of NGSS?

Conceptual Framework

Shulman's (1986) PCK framework of merging content knowledge with pedagogical knowledge was the framework that underpinned this study of how teachers' pedagogical and content knowledge of the three dimensions affects how they teach the standards. Shulman specified three essential components of teaching in his framework: content knowledge, PCK, and curricular knowledge. Content knowledge can be defined as "the amount and organization of knowledge per se in the mind of the teacher" (Shulman, 1986, p. 9). PCK can be described as the content "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p. 9), and curricular knowledge is the vertical and horizontal knowledge of the subject taught. Shulman argued that knowing the subject matter and general pedagogical practices are not enough to establish good teaching (Bouchard, 2021). Teachers need to know how to blend content with pedagogy to create a practical learning experience for students.

Teachers need the proper PCK to implement the NGSS. Teachers should have a complete understanding of how the three dimensions—DCIs, CCCs, and SEPs—interrelate to create a three-dimensional performance expectation. They also have to judge which pedagogical practices can be utilized to successfully convert content into teaching approaches that can teach the three dimensions and create meaningful experiences where students actively do science (Bouchard, 2021).

I used Shulman's (1986) PCK framework to explore how teachers use instructional practices that integrate their knowledge of the three dimensions of NGSS to deliver three-dimensional instructions. Shulman's PCK framework was the basis for the RQs that I used to investigate how teachers integrate their PCK and curricular knowledge when choosing and implementing instructional practices that can teach the three-dimensional content of NGSS. Shulman's PCK framework also informed the data collection; I drew from the framework to develop the interview questions I asked to examine whether teachers have the content knowledge of the three dimensions of NGSS, what PCK they have, and how to choose and implement instructional practices that integrate and teach three dimensions of NGSS. Shulman's PCK framework also undergirded the data analysis; I used the thematic codes from the framework as priori codes during analysis. I used the framework to organize codes into themes. Moreover, the framework provided the criteria needed to analyze lesson plans and classroom observation notes to show that teachers comprehend the three dimensions of NGSS and accordingly choose instructional practices that can teach the three dimensions of NGSS.

Nature of the Study

This was a qualitative research exploratory case study. The key focus of this study was understanding teachers' experiences and attitudes; therefore, qualitative research was the right choice. In a qualitative case study, a researcher describes the interactions of the bounded unit within a particular phenomenon (Burkholder et al., 2016). A researcher conducting an exploratory case study develops explanations for the same set of events for future inquiries (Yin, 2009). The objective of this study was to describe how elementary science teachers who use NGSS standards choose and implement instructions that integrate the three dimensions of NGSS when teaching. To achieve a complete picture of teachers' implementation of the standards and the practices used to teach NGSS, I used various data sources. I gathered data by interviewing 10 elementary science teachers, exploring the same teachers' lesson plans, and observing the same teachers deliver a science classroom. This qualitative analysis may improve understanding of what teachers need when unpacking and teaching NGSS. This knowledge can potentially inform the development of professional development schemes to address such needs.

Definitions

Content knowledge: The body of knowledge that assists teachers in asking questions about, and providing explanations of, the specific subject matter they teach (Shulman, 1986). Science content knowledge is inclusive of teachers' comprehensive knowledge of the semantic and syntactic structure and key concepts of the life sciences, physical sciences, and earth and space science as well as engineering design process (Krepf et al., 2018).

Crosscutting Concepts (CCCs): Overarching concepts that can be taught across the different disciplines of science and engineering to help students bridge disciplines and connect ideas (Tuttle et al., 2016). CCC offers a framework to organize and connect knowledge from different disciplines into a systematic and logical scientific interpretation of the world (NRC, 2012).

Disciplinary Core Ideas (DCIs): Knowledge and ideas that are essential for students to understand a scientific discipline; these are taught by teachers with progressive levels and complexity from K–12 (NGSS Lead States, 2013b). The core ideas encompass four disciplines: (a) life sciences; (b) physical science; (c) earth sciences; and (d) engineering, technology, and application of science (NGSS Lead States, 2013a). These ideas are taught with increased depth and complication across the grade levels, building on students' interests, and can be used to understand other concepts (Tuttle et al., 2016).

Knowledge and Human Dubai Authority (KHDA): The legal authority established by Law No. 30 of 2006 in Dubai, UAE, to supervise the quality and development of private education in Dubai (KHDA, 2017).

Next Generation Science Standards (NGSS): Achieve, NSTA, AAAS, NRC, and 26 lead states developed the NGSS K–12 science standards in 2013 as an outcome of the *Framework for K–12 Science Education* (NRC, 2012). These standards set the expectations of what students should know and can do at every grade level (NGSS Lead States, 2013c). They are performance expectations built on the distinct yet equally important three dimensions recommended by the Committee on a Conceptual Framework for New K–12 Science Education Standards (NGSS Lead States, 2013a). States, education stakeholders, scientists, teachers, leaders, and researchers developed these standards. According to experts, the implementation of NGSS can reform U.S. public K–12 science education to prepare students for college and career (Harris et al., 2017).

Pedagogical content knowledge (PCK): Ways of representing phenomena to increase understanding among others (Shulman, 1986). PCK is an instructional approach to organizing, representing, adapting, and presenting information to help students comprehend the taught subject matter (Magnusson et al., 1999). PCK is what distinguishes science educators from scientists as it enables educators to transform scientific knowledge into a context that can facilitate the learning of students (Kang et al., 2018).

Science and engineering practices (SEPs): The set of behaviors that scientists use as they inquire about the real world (NSTA, 2014a). Students need to engage in practices to actively understand science. The practices represent the knowledge and reasoning skills that students require to think and act like real scientists (Kang et al., 2018).

Three-dimensional science learning: The view that science education in K–12 should be composed of three dimensions—DCIs, CCCs and SEPs—and that these three dimensions should be "integrated into standards, curriculum, instruction, and assessment" (NRC, 2012, p. 2). The approach was recommended by the committee in charge of developing the science education framework and standards. Three-dimensional learning links scientific inquiry represented by the eight practices to knowledge represented by seven crosscutting concepts and ideas within each discipline of science (Jin & Mikeska, 2017).

Assumptions

I assumed that the participants were currently employed as teachers at American private schools in Dubai, UAE, and were teaching science at elementary grades as part of their responsibilities. I also assumed that the participants were honest about their years of experience and credentials and that they answered all of the interview questions with fidelity and accuracy. Having these assumptions enabled me to explore the phenomenon in question: teacher's preparedness to implement instructional practices that integrate the three dimensions of the NGSS.

Scope and Delimitations

The investigation in this study was bound to the distinguishing characteristics of the target population, full-time elementary teachers of different nationalities who prepared lesson plans and taught NGSS at American private school Dubai, UAE to non-native speakers of English. To gain a deeper understanding of how well teachers are prepared to implement the standards, I focused on participating teachers' perceptions of the three dimensions of NGSS, their knowledge of instructional practices, and their choice of practices to implement three-dimensional NGSS. The framework was a guide to determine how teachers integrate content knowledge of the three dimensions of NGSS with instructional practices to implement NGSS. This focus helped me to frame the interview questions and analyze the data. Results from this research might be transferable to similar elementary teacher populations within comparable circumstances.

Limitations

The study was limited to the confines of the examined population and their environment. Applications outside the population sampled may be limited. This research was also limited to circumstances and answers targeting NGSS implementation and did not address any other standards or reforms. The small sample size might have limited the potential to achieve concept saturation. With the study being confined to a certain geographical region, transferability to other regions in other geographic locations with different demographic population might be limited.

Significance

There are insufficient studies that target teachers' choice of three-dimensional instructions for NGSS. As such, this study provided an in-depth understanding of how teachers choose and implement instructional practices to efficiently teach the three-dimensional standards of NGSS. The outcomes of this study explained teachers' preparedness to teach three-dimensional standards, what teachers considered successful practices that can integrate the three dimensions of NGSS, and the support they needed to provide effective instruction. With the scarcity of research about NGSS in the UAE, this study could help teachers as they plan for the standards and teach them. The study results promoted positive change by providing information on what teachers are doing to implement the three dimensions of NGSS. This information could help school administrations decide on what training is needed to better assist teachers in delivering three-dimensional instructions. The proper implementation and training could potentially lead to better success for students in learning science, which can create 21st-century students who are science and engineering literate and may increase STEM motivation (Barrett-Zahn, 2019; Hayes et al., 2019; Kang et al., 2018). Success in Teaching Science at schools would help increase student achievement in international assessments and achieve the requirements of the UAE National Agenda.

Summary

STEM careers are in high demand in the global market. The 21st century requires that students be STEM- and science-literate. To prepare students to compete globally and to equip them with 21st-century skills, the standards for science had to undergo reformations to match the changes and needs in global fields. A *Framework for K–12 Science Education* proposed a different perspective for teaching science by moving away from content-driven instruction to three-dimensional learning (NGSS Lead States, 2013a). The NGSS was subsequently released to fulfill the vision by introducing performance expectations built on three dimensions: (a) DCIs, (b) CCCs, and (c) SEPs (NGSS Lead States, 2013c). In line with the global changes, the UAE proposed a vision to compete globally by enhancing all aspects of life, including education. All private schools in Dubai must follow recognized American standards, which has resulted in their adherence to NGSS. Teachers find the standards complicated and challenging to implement due to the standards' complex three-dimensional content according to the head of department. Understanding how teachers apply instructional practices that incorporate the three dimensions of NGSS may help stakeholders to understand teachers' struggles when choosing practices that promote three-dimensional learning and to consider future professional development to assist teachers to address these struggles.

In Chapter 2, I review key literature, including on the status of science education and efforts in the United States and internationally in the UAE to improve science education. The literature reviewed in the chapter shows the need for the development of the NGSS standards and the shifts associated with implementing these standards. I also examine literature related to current research in the field of teachers' implementation of these standards and their experience with three-dimensional learning, STEM integration, and engineering. In the chapter, I also review the conceptual framework of PCK and its effect on the implementation of NGSS. The framework provided a lens to understand teachers' preparedness to teach NGSS.

Chapter 2: Literature Review

There was a need to better understand how teachers use their PCK to provide three-dimensional instruction that meets the needs of NGSS. In this study, I explored the instructional practices that teachers can choose to incorporate the three dimensions when implementing NGSS. It was also essential to understand how teachers integrate their content knowledge of the three NGSS dimensions and their pedagogical knowledge to decide on which instructional practices can support three-dimensional learning.

To address the lag of scientific achievements and to increase the number of STEM graduates, educational leaders and policy makers have made several fundamental reforms to science education in the United States over the last few years. With international benchmarking assessments continuing to show disappointing achievements for U.S. students in comparison to their international peers (see Organisation for Economic Co-operation and Development, 2012, 2019), there has been increased recognition of the need to improve education in the United States (Braun & Singer, 2019; Moreno, 1999). The poor results drew attention to the status of U.S. education and its ability to prepare U.S. students to compete in global markets. The other prevailing issue that appeared was the need for more students to major in STEM careers. There is a significant concern that there are not enough students entering the STEM fields (Wong et al., 2023) and that most of the current students graduating from high school are STEM illiterate (Mathis et al., 2017). These issues fostered discussion of revamped standards that can create science and engineering literate citizens and reflect the skills and advancements of the 21st century (NRC, 2012).

UAE leaders have carried similar reforms. They envisioned their country becoming one of the world-leading education providers (Al Maktoum, 2014). STEM and innovation are highlighted and included in the school curriculum. UAE leaders started taking steps to elevate the level of education provided in both public and private schools. The Ministry of Education, which supervises the work of public schools, conducted a series of restructurings to fix the overall quality of education. Private schools, which are the for-profit autonomous international schools, are overseen by newly developed entities that are supervised by the Ministry of Education; areas of oversight include the implementation of current internationally recognized standards to ensure that all private schools provide high-quality education for the students (UAE Ministry of Education, 2021). All schools now follow internationally recognized standards for the curriculum of study. Therefore, American schools in the country follow the national Common Core State Standards (CCSS) and NGSS standards.

NGSS standards are distinctive from the former science standards. The standards are not content driven, so the best way to implement NGSS is by integrating all three dimensions (Castonova & Chenobilsky, 2020; Houseal, 2016). This three-dimensional model requires pedagogical and instructional shifts inside the science classrooms (NGSS Lead States, 2013a; Smith, 2020). The shifts carried by NGSS put pressure on teachers to modify their teaching practices to meet the demands of NGSS. Asking educators to realign what they have been teaching before or to adapt preexisting curricula to match the core ideas of NGSS will not fulfill the requirements of NGSS (Windschitl & Stroupe, 2017).

To fully implement NGSS, teachers need to revamp their teaching practices and immerse the students in scientific inquiry and engineering design practices where students have real opportunities to explore real-world problems and design solutions. The ability of elementary teachers to carry such a task is a concern as most teachers at these grade levels focus on language development and mathematical literacy and lack the necessary background in teaching science inquiry or engineering design (Tuttle et al., 2016). Plumley (2019) explained that 77% of elementary teachers are well prepared to teach English Language Arts (ELA), and 73% are well prepared to teach mathematics but only 37% feel well prepared to teach science. The same report showed that only 3% of the teachers have had a college course in engineering. Teachers who understand the pedagogical shifts required by NGSS still fail to implement NGSS in their classrooms (Kawasaki & Sandoval, 2020; Shernoff et al., 2017).

Most researchers have focused on teachers' attitudes towards NGSS; few have examined the effective instructional practices teachers use to implement the three-dimensional learning of NGSS. NGSS standards define what students should be capable of doing at every grade level without showing teachers how practices would look like in a classroom setting (Pasley et al., 2016). Researchers have identified project-based learning as one effective practice to integrate the three dimensions (Holthuis et al., 2018; Krajcik et al., 2023; Shernoff et al., 2017), but teachers use a variety of other practices and strategies, and it will be essential to look at their effectiveness in teaching NGSS.

This chapter includes an analysis, synthesis, and evaluation of relevant literature regarding the reform of education and science standards in the United States and the

UAE, clarification on the uniqueness of NGSS and its emphasis on engineering, and teachers' implementation of NGSS as three-dimensional learning and as a critical reform for STEM. The literature review includes synthesized themes based on U.S. science standards reformation, UAE's educational reform and status of science education, the uniqueness of NGSS standards with a focus on STEM, and the effect of NGSS's vision on the implementation with a focus on elementary teachers. The focus on elementary teachers' understanding and implementations of three-dimensional instructions provided a lens to evaluate the current literature. Shulman's (1986) PCK framework provided a context to link teachers' choice of instructional practices with their content knowledge of NGSS and PCK of how to teach science in general and NGSS in particular. Findings from current relevant studies are helpful in evaluating the current status of NGSS, teachers' understanding of three-dimensional learning, teachers' experience with engineering and STEM, and the successful practices that they use to implement NGSS within UAE as a focus. I evaluated the results through the lens of Shulman's framework to identify whether elementary teachers in the UAE are prepared to teach the three-dimensional standards.

Literature Search Strategy

Key search terms are designated to direct the literature review process. As part of the search process, I used descriptors such as *science education reform in U.S.*, *NGSS implementation*, *STEM learning*, *STEM teaching*, *education in the United Arab Emirates* or *UAE*, *pedagogical content knowledge*, *engineering design process*, *STEM integration*, *elementary teachers*, *implementation of NGSS*, *three-dimensional learning*, *NGSS* *professional development*, *NGSS in the Arab world*, *science and engineering practices*, and *crosscutting concepts*. I used multiple databases available from Walden University Library, including Sage Publications, ERIC, Education Source, Taylor and Fransic, Academic Search Complete, Science Direct, National Academies Press, OECD iLibrary, ProQuest Central, and the search engine Google Scholar. I reviewed extensive search to identify the current status of NGSS implementation, elementary teachers' preparedness to teach NGSS, and teachers' understanding of three-dimensional learning. The search yielded few studies that addressed teachers' perceptions of instructional practices for the teaching of the three dimensions of NGSS or their perceptions of NGSS implementation in UAE, thus justifying a gap in the current literature.

Conceptual Framework

For the last 3 decades, researchers have assumed that if teachers have the required knowledge in a content area, they will be able to successfully teach students (Doering at al., 2009). Teachers who have in-depth content knowledge are assumed to be able to teach science successfully, but this has shown to be different since the release of NGSS. With the changes that NGSS has brought into the science education field, there was a necessity to understand how teachers choose and implement instructional practices that can integrate and teach the three dimensions of NGSS at the elementary level. When teachers implement three-dimensional learning, they need to utilize content knowledge, curricular knowledge, and PCK in choosing the proper teaching practices.

Teachers face many challenges and need clear direction on how successful instruction and curriculum are in an NGSS classroom (Roseman et al., 2017). NGSS shifted the focus from learning content to what students can do with the content they learn. To successfully implement NGSS, it is not enough that teachers know science content; they need to use such knowledge to immerse students in real-life situations where students use the three dimensions to construct explanations or design solutions. Most importantly, teachers should be capable of integrating their general pedagogical knowledge of teaching science with their knowledge of NGSS and the UAE school context to deliver three-dimensional instruction for students in a UAE classroom successfully.

Over the past years, researchers understood the need for various knowledge forms, specifically the need for PCK to inform teachers' practices in the classroom (Doering et al., 2009). Shulman (1986) defined PCK as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction" (p. 8). Shulman also recognized different components of knowledge: content knowledge, general pedagogical knowledge, curriculum knowledge, PCK, knowledge of learners, knowledge of educational contexts, and knowledge of educational ends, purposes, and values. The work of Shulman (1986) can create an understanding of how teachers can help students learn. PCK is the integration between teachers’ knowledge of the teaching methods and their knowledge of the content being taught within the context of the classroom and community where they teach (Kang et al., 2018). This knowledge of content and pedagogy makes PCK the most powerful tool that includes illustrations, explanations, analogies, or demonstrations used to make a subject comprehensible for the students (Shulman, 1986).

Teachers find it challenging to translate their subject knowledge into classroom teaching, so PCK is looks at how teachers transform their content knowledge into classroom teaching (Meredith, 2019). With the current challenges that teachers face in implementing NGSS, Shulman's (1986) PCK framework will provide the lens to examine how teachers use their knowledge of the three dimensions of NGSS when designing materials and instruction that fulfill the requirements of the new NGSS standards. Understanding the challenges can highlight UAE science teachers' readiness to implement three-dimensional standards in their classrooms.

Literature Review Related to Key Concepts and Variable

In this literature review, I examined the publications and results of peer-reviewed journals to fully understand the science education status preceding and following the development of NGSS. The research within the last 6 years focused on teachers' preparedness to work with the standards and describe the changes teachers need to do to implement NGSS successfully. The research examined teachers' abilities and their efforts to teach STEM or engineering through the successful implementation of science and engineering practices required by NGSS. Other researchers study how teachers perceive the three dimensions of the standards as a base for three-dimensional teaching. The organization of this literature review follows a format that outlines research findings in the following areas: (a) reform of U.S. science standards leading to the development of NGSS, (b) UAE educational reform and science education, (c) NGSS, (d) current status of NGSS implementation at elementary grades, (e) three-dimensional learning, (f) STEM integration, (g) engineering within NGSS, and (h) PCK.

The Influence of U.S. Science Standards Reform on the Development of the Next Generation Science Standards

It is essential to look at the history and events that led to the formation of NGSS standards to understand their complexity better. States are fully responsible for developing their standards based on what they consider essential to teach. The development of standards at state levels resulted in discrepancies in the level of education provided between one state and another. With individual states having complete control over K -12 education, standards reform means fixing 50 autonomous educational systems (Dove, 2002). Educational reform has been an area of focus for a long time in the United States. Boyd (2022) echoed early calls for education reform by highlighting the threat of "mediocrity" in education as the foundation for creating a generation of students who cannot compete in a global market. Boyd (2022) cited the decline in the achievement of American students in benchmark exams compared to their international peers and called for severe reforms in standards, teaching, and curriculum. It also described Americans needing more essential skills, literacy, and training to compete in the new global era. It highlighted the importance of rebuilding the educational system and teaching to equip students with the skills required for college and careers.

Science reformation has been attempted in many ways over the subsequent years, with more hope of utilizing national standards as facilitators of change to improve science education (Bybee, 2006; Nollmeyer & Bangert, 2017). The first national standard reformation initiative resulted in the development of the National Science Education Standards, which were released in 1995 (NRC, 2015). These standards described a new vision where all students become actively engaged in the inquiry that should help them understand and interpret natural phenomena and events, which will create science-literate citizens (Moreno, 1999). While most of the states used the National Science Education Standards as the basis for developing their science state standards, the results of the National Assessment of Educational Progress and the Trends in International Mathematics Science Study (TIMSS) and rankings from the Program of International Student Assessment (PISA) still showed low science proficiency among U.S. students especially when compared to the international scores (Harris et al., 2017). With U.S. science achievement ranking in 24th place internationally, there was a call for new standards that are not too broad and a need to develop new methods for teaching students to better prepare them for future careers (Harris et al., 2017).

When analyzing TIMSS's and PISA's top-performing countries, researchers noticed that such countries have common national and coherent standards. Shmidt et al. (2005) analyzed the results of the Third TIMSS to show that it is not enough to have common content standards. The study suggested that the United States should build a coherent and rigorous set of standards that can articulate a national framework to compete with high-achieving TIMSS countries. This study also proposed that U.S. educational leaders should develop new standards to move away from the "mile-wide-inch-deep curriculum" into more focused, progressive, and coherent standards that can build deep understanding (Bybee, 2006; Shmidt et al., 2005, p. 526).

The *Framework for K–12 Science Education* was released in 2011 to provide a refurbished vision for teaching science by providing a coherent nature to the standards taught at each grade level. The framework added the engineering performance expectations to the grade band endpoints and engineering design within the science practices (Gale et al., 2019). The framework included three fundamental criteria:

- to move away from the mile-wide-inch-deep standards into progressive, developmental standards that can help students build on the acquired skills, knowledge, and abilities into a more structured understanding of how the world works,
- to focus on fewer core ideas or concepts per grade level to give enough time for students to investigate each of the concepts at a deeper level of understanding and
- to integrate science and engineering knowledge with practices that can help create a meaningful experience beyond memorizing facts (NRC, 2012).

The framework is not a set of standards but rather a vision of how the standards should be. The *Framework for K–12 Science Education* was designed prior to writing NGSS to inform how the new standards would be. These standards should transform science classrooms from situations where students learn the science content to opportunities for students to actively engage in doing science through applying the three-dimensional design of the standards (Houseal, 2016; Seung et al., 2023). NGSS were developed based on the changes occurring and the student's situation, so they are set to prepare students for college and career fields (Rachmawati et al., 2019). NGSS are not just U.S.-specific standards. While the NGSS document was developed in the United States to persuade state-level decision-makers to follow shared educational goals and reforms, the influence of the NGSS extends beyond the United States to have worldwide implications (Hufnagel et al., 2018; Nawafleh et al., 2022). International schools adopt NGSS as the standard for teaching science outside the United States. Following NGSS standards causes concerns as the changes required by NGSS may not match the status of science education outside of the United States.

UAE Educational Reform and Science Education

The UAE is a relatively a new wealthy nation in the Arabian Gulf region celebrating 48 years of existence. The country has seven emirates, including Abu Dhabi, the biggest emirate with the capital city of Abu Dhabi, and Dubai, the second biggest emirate with Dubai, the global city and the business hub. This oil-rich country boasts a Western twist in an Eastern context. Like all countries that are debating to improve their educational status, the UAE decided to link educational reform to the country's economic agenda (Gaad et al., 2006). As the country was attempting to move into a more diverse economy versus the economy that relies heavily on oil production, the UAE has decided to transition into a knowledge-based economy to position itself as an economic, touristic, and commercial leader (KHDA, 2017). By linking education to its economic growth, the UAE will create a knowledge-based economy that will enable it to move away from fossil fuel dependency. A knowledge-based economy is an economy where a country uses knowledge to create a competitive economy that can compete internationally with knowledge application in innovation, research, development, and entrepreneurship

(Chorev & Ball, 2022; Dima et al., 2018), which the UAE seeks. In UAE's Vision 2021, the country set a national priority of establishing a competitive knowledge economy and developing first-rate education as central aims to achieve international recognition (Matsumoto, 2019).

The UAE has both public and private school sectors. Private international schools in the UAE are scattered across all the emirates. In Dubai, 365,572 K–12 students attend 220 private schools (KHDA, 2023a). Expat students are not permitted to attend public schools; therefore, international schools cater to the large expatriate community and prepare students for universities, with their numbers increasing (Mahfouz at al., 2019). UAE private international schools follow different curricula and standards based on their international affiliation. American-curriculum schools have proven to attract students with continuous growth in school numbers over the last years (Government of Dubai, 2022; Pennington, 2017). International U.S. schools in UAE adopt U.S. educational trends and follow U.S. standards, curriculum, and assessment to create the authentic U.S. experience for their students (Mahfouz et al., 2019). Most U.S. international schools in the UAE follow the CCSS and NGSS standards (Eltanahy & David, 2018).

Like all Arab countries, the UAE prefers to adopt global policies that introduce imported models led by international consultants to reform its educational system (Aydarova, 2017). The UAE hired international organizations to reform the country’s standards to elevate the quality of education at public schools. To monitor education across both sectors, the UAE formed internal entities to ensure high quality of education in its public and private institutes and enrolled in international benchmarking assessments to position itself globally (Mohamed & Morris, 2019). In a small UAE nation, the government has created three management bodies within the federal education system. ADEK oversees and reforms the work of public and private schools in the Emirates of Abu Dhabi, the KHDA oversees the work of private schools in the Emirate of Dubai, and the Federal Ministry of Education with education zones regulates both private and public schools in the rest of the emirates (Ridge, 2015a). To check the efficiency of the reform measures, the UAE strategically chose to participate in PISA and TIMSS to ensure that the country reaches its educational goals (Morgan & Ibrahim, 2019).

The UAE has implemented different practices and strategic plans to elevate and standardize the quality of education across the schools. However, the education provided at UAE private schools, in general, and American schools, is still a concern. According to the 2022-2023 inspection report of KHDA, 35% of inspected American schools rated acceptable or less (KHDA, 2023b). Parents and teachers expressed dissatisfaction with the quality of education provided at private for-profit schools mainly that they do not always get value for money (Ridge, 2015b). The quality of education at private schools results in significant concerns about the fidelity of implementing the newly developed NGSS and CCSS standards at private American schools.

UAE schools practice a borrowing philosophy where they hire international teachers, use international curricula and textbooks, and conduct professional development through international companies and consultants (Morgan & Ibrahim, 2019). Expat teachers often cite a lack of job security, heavy teaching load, and low salaries as factors that negatively impact their satisfaction (Ibrahim & Al Teneiji, 2019). This hiring philosophy of expatriate educators resulted in what Jackson (2015) explained as the "Never Fail a Nahyan" (p.767) approach, where expatriate teachers strategically use a paradox of adopting both student-centeredness with extreme teacher-centeredness to combat students' lack of motivation, interest, and responsibility to learn (Jackson, 2015).

here needs to be more quantitative or qualitative research on the quality or status of science education in the UAE. Al Naqbi (2019) studied elementary preservice science teachers enrolled in elementary mathematics/science education programs in the UAE. The study examined teachers' experience with inquiry-based instructions before teaching and their current implementation of inquiry-based instructions in elementary classrooms. Results from the study showed that none of these teachers had any previous experience with inquiry-based instructions in their secondary studies or during their college studies. Teachers cited that their high school experience focused on content memorization in a traditional, teacher-centered classroom. Students did not have opportunities to conduct open-inquiry labs and were engaged in structured activities. Preservice teachers still needed to be able to differentiate between research and inquiry teaching and had inconsistent views of what inquiry-based instructions are after their college studies. The study interviews showed that these elementary preservice science teachers face various hindrances that would not allow them to implement inquiry-based instructions in their classrooms, such as the dominance of traditional teaching approaches, shortage of teaching resources, and lack of support (Al Naqbi, 2019).

A study conducted by Eltanahy and David (2018) to investigate the predominant teaching practices used by science, math, and technology teachers at American private schools in UAE showed that the UAE teachers are at a stage of creating "engaging lectures" (p. 287) by combining traditional approaches with some innovative practices to engage their learners. While some teachers believed in shifting their paradigm to use innovative teaching practices, most still face predominant hindrances, such as the demand to cover an extensive curriculum, making it more convenient to follow a traditional lecturing approach to avoid accountability. The study also revealed that not all American schools had embraced innovative teaching practices, and most continue to use the traditional approaches of lecturing, indicating a mismatch between the documented curriculum and what teachers implement in the classrooms, mainly due to class sizes and workloads (Eltanahy & David, 2018).

Although private schools conduct training and professional development to assist teachers, UAE teachers' preparedness to implement new standards and NGSS still needs to be evident. Researchers widely agree that NGSS requires extensive professional development to help teachers understand and implement NGSS (McNeill, 2021; Nollmeyer & Bangert, 2017; Shernoff et al., 2017; Tuttle et al., 2016). A qualitative study on elementary science teachers ($N = 23$) conducted by Kruse et al. (2020) showed that professional development targeting conceptual change helped teachers develop conceptions of matter that were better aligned with the performance expectations of NGSS. Another study by El Afi (2019) showed a significant concern for the efficacy of professional development on UAE teachers. Most professional development schemes are of irrelevant context and culture. Private companies conduct these professional development sessions utilizing Western trainers who try to convince teachers of methods that work primarily in schools with native English speakers. Teachers echoed similar concerns in a study conducted by Buckner et al. (2016), where teachers confirmed that they participated in professional development training but still felt that they needed more targeted professional development that was not repetitive or irrelevant. Research that examines teachers' implementation of NGSS in the UAE is missing.

Next Generation Science Standards

The Lead States composed the NGSS in line with the recommendations of the *Framework for K–12 Science Education* (NGSS Lead States, 2013b). The framework provided the research and rationale for why science education needs to look very differently than what it looks now (Windschitl & Stroupe, 2017). The framework and the standards aim to create science-literate students and change science practices inside the classroom (NRC, 2012). The development attempted to unify science education in the United States following the formation of common standards in Math and English. NGSS are different standards as they are the first standards that have a three-dimensional nature, promote engineering design, and have explicit connections to the CCSS for Mathematics and ELA.

NGSS standards are the first three-dimensional standards. NGSS standards provide grade-level performance expectations linked to three dimensions: SEPs, CCCs, and DCIs (NGSS Lead States, 2013c). To understand performance expectations, teachers must explore each dimension separately then intertwine them to get the complete picture (Danielson & Matson, 2018). NGSS is all about immersing students in real-life situations where they apply the knowledge that they have acquired in constructing explanations and designing solutions. Teachers must integrate the three dimensions into their teaching, curriculum, and assessment, as teaching each dimension alone would provide an empty and irrelevant experience (National Academies of Sciences, Engineering, and Medicine, 2015).

With more than 44 states having fully or partially adopted NGSS, there is a growing challenge with the implementation of the new standards (Miller et al., 2023). Schools are struggling with the implementation as the standards call for three-dimensional learning and mandate a shift to inquiry-based teaching, which is very complex compared to traditional teaching (Andersson et al., 2021). NGSS puts an equivalent focus on science inquiry and engineering practices. To better prepare students for the STEM career field, NGSS committed to integrating engineering education into K–12 science education by elevating engineering design to the same level as scientific inquiry in every grade (NGSS Lead States, 2013a). The engineering practices within NGSS provide real-life context for science and mathematics to help students adapt to a fast-evolving and changing world (Gale et al., 2019). The main goal of adding the Engineering Design Process (EDP) into science education is not to create more engineers but critical consumers of science that can be related to daily life (NRC, 2012). When students are actively engaged in the EDP, they can become critical thinkers who can solve problems related to daily life (Dailey, 2017; Han & Kelley, 2022).

NGSS standards are also the first standards that purposefully made explicit connections to the CCSS of ELA and Mathematics (NGSS Lead States, 2013a). The connection between CCSS and NGSS allows teachers to create interdisciplinary learning opportunities to collaborate and engage students in the development of skills that appear in both CCSS and NGSS (Hayden & Eades-Baird, 2020; Lee, 2017). The NGSS document specifies how each performance expectation links to CCSS. CCSS and NGSS documents address the same foundational concepts and practices (Lee, 2017). Hayden and Eades-Baird (2020) explained that CCSS and NGSS require students to develop similar literacy skills within inquiry-based science instructions. Novak (2016) explained that these skills include writing arguments to support claims using evidence and reasoning skills, thus creating a common framework between the different subjects.

NGSS focuses on shifting science education to help prepare students for college and career by concentrating on fewer core ideas that coherently progress across grade levels and integrating these core ideas with science and engineering practices with a particular focus on integrating engineering and technology (Harris et al., 2017). NGSS standards shift science from studying content to practices that allow students to apply science and engineering to a real-world situation and design solutions for real-world problems (National Academies of Sciences, Engineering, and Medicine, 2018). The engineering practices within NGSS teach students how to conduct the engineering design process and develop essential skills needed in the field of work, such as collaboration, decision-making, and problem-solving (Wendell et al., 2017). Han and Kelley (2022) conducted a concurrent think aloud study on high school students over 3 years ($N = 81$), illustrating that the integration of science and engineering practices enhances students' thinking and creativity. The job field and employers seek these skills in their prospective employees.

Current Status of Next Generation Science Standards Implementation at Elementary Grades

Although many elementary teachers believe science should be student-centered, traditional, and conservative teaching practices persist, including failing to engage students in sensemaking (Bernhard, 2023). NGSS standards require fundamental shifts in teachers' classroom practices. With NGSS, teachers must reconsider how students understand content, what content they should teach, and how to engage students in constructing a conceptual understanding that can progress over time (Roseman et al., 2017). Teachers should be able to support students in doing science through a three-dimensional approach composed of integrating DCIs, SEPs, and CCCs (Kang et al., 2019). Only by connecting the three dimensions of science can teachers equip students with the reasoning skills that would enable them to create a network that can assist in developing explanations or designing solutions (Kang et al., 2018).

Teachers' understanding of NGSS and readiness to implement the instructional shifts associated with these standards are a concern. Some teachers feel that they do not have the support needed or the right tools to unpack and implement NGSS. McFadden (2019) explained that teachers have conflicting views on what qualifies as high-quality instructions that align with NGSS, and they often face school climates that do not promote change. Harris et al. (2017) conducted a study on 214 teachers from 16 different states. They showed that teachers have significant concerns when implementing the NGSS, including changing the curricula to reflect NGSS, the lack of resources, the lack of time needed to finish the syllabi, and the lack of training in some states. The study concludes that support and resources are needed to assist teachers in understanding and implementing NGSS.

With a lack of confidence to teach NGSS, teachers find NGSS overwhelming and complicated. Elementary teachers struggle the most when implementing the NGSS as they lack the suitable material for hands-on inquiry and the required science content knowledge, which can limit their motivation and create self-doubt and insecurity in teaching science (Barrett-Zahn, 2019; Smith & Nadelson, 2017). Elementary teachers also lack confidence in teaching the content of science. Most elementary teachers have minimal knowledge of how to teach science and tend to focus more on developing literacy skills and mathematics (Dailey, 2017; Plumley, 2020). Most importantly, elementary teachers need help teaching inquiry and engineering practices of the NGSS as they fail to immerse students in the experiences required by NGSS (Kawasaki & Sandoval, 2020; Tuttle et al., 2016).

To assist teachers in understanding and implementing NGSS, extensive, and targeted professional development that can change teachers' mindset on how science should look like in a classroom is needed (Barrett-Zahn, 2019). NRC (2015) calls for multiple years of extensive professional development to support the transitioning efforts and instructional pedagogical shifts that NGSS requires. Elementary teachers need professional development to demonstrate how to integrate the crosscutting concept with the practices and disciplinary core ideas to create three-dimensional learning. They also need targeted professional development that shows them how to integrate engineering design within science instructions. Research shows that professional development has a positive effect on teachers' performance. Short (2006) indicated a strong correlation between high-quality professional development and the implementation of teaching practices consistent with the curriculum reform needed, which can be a powerful tool that can promote positive change in teachers' attitudes and practices.

Most teachers feel unready to teach NGSS as the preparation programs for teachers do not equip them with the tools needed to address engineering practices (Christian et al., 2021; Hammack & Ivey, 2017). Even with professional development, teachers might still feel they cannot fully understand all the features of scientific inquiry and engineering design defined in NGSS to know how to translate it to classroom practices (Tuttle et al., 2016). Lewis (2023) conducted a case study of two Biology teachers engaged in long-term professional development. The study revealed that teachers engaged in professional development might not adopt pedagogical approaches that align with the reform. Harlow's (2014) study showed different ways teachers transfer the knowledge acquired by professional development into a classroom setting. Some teachers tended to transfer both pedagogical practices with the content; some changed the content to fit into their pedagogical practices, while others showed no transfer. Alternatively, a study by Hayes et al. (2019) showed that teachers have aligned beliefs with the reforms but lack the knowledge to translate these beliefs into the proper teaching practices. The study proved that programs that can infuse practices and tools with pedagogical knowledge, hold high expectations, support teachers, and give them opportunities to reflect on students' learning positively impact teachers' implementation of the standards (Hayes et al., 2019).

Three-Dimensional Learning

NGSS are three-dimensional standards. Each NGSS performance expectation links to the three dimensions: DCIs, SEPs, and CCCs. DCIs are divided into four disciplines: (a) life sciences, (b) earth and space sciences, (c) physical sciences, and (d) engineering and technology sciences (NRC, 2012). There are eight science and engineering practices: (a) asking questions and defining problems, (b) developing and using models, (c) planning and carrying out investigations, (d) analyzing and interpreting data; (e) using mathematics and computational thinking, (f) constructing explanation and designing solutions, (g) engaging in argument from evidence, and (h) obtaining, evaluating, and communicating information (NRC, 2012). The standards also specify seven crosscutting concepts: (a) cause and effect, (b) structure and function, (c) systems and system models, (d) scale proportion and quantity, (e) stability and change, (f) energy and matter, and (g) patterns (NRC, 2012).

Teachers must understand that the three dimensions of NGSS are inseparable and know how to successfully integrate them into lessons to implement NGSS (Froschauer, 2017). Teachers mainly focused on teaching science content for so long that it became hard to visualize the links between the three dimensions. Castronova and Chernobilsky (2022) conducted a qualitative analysis on the reflections of K–12 science teachers teaching NGSS (*N* = 165), showing that teachers have different discontentment levels with the three dimensions of NGSS. Teachers often have misalignment between their current teaching and the reform requirements when delivering CCCs, DCIs, and even SEPs. Studies have consistently shown that teachers scored low averages on practices involving modeling, argumentation, and explanation (Hayes et al., 2016; Seung et al., 2023). The low scores proved that these practices were the least used by teachers in their classes. Moreover, teachers often struggle with integrating crosscutting concepts as they are considered additions to lessons rather than a way of thinking (Talanquer, 2019). Therefore, by not recognizing the connections between the three dimensions, teachers end up teaching each of these dimensions in isolation.

Understanding how to create or align three-dimensional curriculum material is still a struggle. Lowell et al. (2020) specified that "NGSS-designed instruction should be phenomenon-based, three-dimensional, support student epistemic agency, and coherent" (p. 10). The case study focused on two classrooms that had adopted an aligned curriculum and showed that the curriculum did not satisfy the requirements of NGSS (Lowell et al., 2020). Fulmer et al. (2018) examined how well the available research described the alignment efforts to ensure the compatibility of the assessments, pedagogy, and curriculum with the interpretations of NGSS. Their conceptual analysis investigated the alignment methods used with the CCSS to review alignment on NGSS. The research showed that although NGSS calls for integrating the three dimensions when developing curriculum, pedagogy, or assessment to teach NGSS, the available research provided little clarity on how to do this. Most alignment studies would either take each dimension separately or take one dimension as a referent to measure alignment. The study concludes that the lack of alignment between the standards, the assessments, and the curriculum material prevents the successful implementation of NGSS.

At elementary levels, NGSS calls on teachers to shift the focus from content to skills, whereas traditional science education has always focused on content. Teachers feel confident when teaching science content but less confident when teaching the practices of NGSS (Kang et al., 2018). Lee and Glass (2019) explained that traditionally and up till now, preservice programs and training prepare elementary preservice teachers to be "generalists" (p.18) as they study, learn, and apply practices that fit to teaching all subjects. This training leaves no time to prepare preservice teachers to learn the details of DCIs or the pedagogical practices that suit elementary science teaching. To help teachers understand and implement the reform of NGSS, teachers need to investigate scenarios of practice where they experience three-dimensional learning, examine how students build knowledge and how teachers support students, and then try to apply these scenarios into their practices, which requires practice-focused professional development schemes (Reiser et al., 2017).

NRC (2012) explained that integrating CCCs with the other dimensions connects and links the different science disciplines. Fick et al. (2022) also explained that CCCs are essential in three-dimensional learning. They serve as a framework for teachers to guide discussions that can build students' understanding of specific topics of DCIs and engage them in SEPs. CCCs provide a lens for students to acquire an extensive understanding and clarify misconceptions about the phenomenon (Fick, 2018). While teachers have experience incorporating practices with science content, they often struggle with integrating the CCCs meaningfully into their lessons (Talanquer, 2019). Most teachers fail to teach the CCCs of NGSS as they lack guidance on integrating the CCCs into their instruction or investigation (Goggins et al., 2019; Kang et al., 2018). Osborne et al. (2018) argued that CCCs are loose, incoherent principles that educators feel confused about interpreting, making them very difficult for teachers to implement.

To help teachers understand what three-dimensional instructions look like, Lowell and McGowan (2022) outlined four key features of the NGSS curriculum: (a) phenomenon-based, (b) student-centered, (c) three-dimensional, and (d) coherent from the student perspective. They explain that these features should help teachers choose materials or modify them to make them NGSS-aligned (Lowell & McGowan, 2022). Jin and Mikeska (2017) suggested three features for a three-dimensional learning curriculum: (a) emphasizing the thinking behind the practices, (b) engaging students in the use of practices, and (c) integrating the practices with the knowledge to create the integration of the three dimensions. They also conclude that designing such three-dimensional activities is a significant challenge for teachers, requiring many examples to show how these practices would look in action. To further elaborate on what three-dimensional instructions look like in classrooms, researchers remind teachers that performing labs and activities does not always qualify as authentic NGSS experience (Colson & Colson, 2016; Dickinson et al., 2020). An authentic NGSS lab experience should look like "authentic scientific research" (Colson & Colson, 2016, p. 52), where students pursue authentic questions, use practices to make sense, and understand the broader context of science and engineering.

Integration of Science, Technology, Engineering, and Mathematics in Education

STEM is linked to a country's economic growth, competitiveness, and living standards (Wright et al., 2019). As the demand increases in developing new ways to better prepare students for future careers, STEM disciplines become of high interest to create critical thinkers and problem solvers (Christian et al. 2021; Isabelle, 2017). There is a growing concern that there are not enough students in the United States prepared for STEM careers, which is essential to keep the United States in an internationally competitive position (Mathis et al., 2017). Teaching STEM at the school level equips students with skills and knowledge that can help them in the future of society (Hoeg & Bencze, 2017; Wong et al., 2023). It would also increase students' interest in STEM, which positively impacting STEM literacy (Whitworth & Wheeler, 2017). NGSS is considered the most critical STEM reform in the United States, and the standards should develop globally competitive students (Hoeg & Bencze, 2017). However, teaching STEM is challenging for teachers and students at all levels, especially in elementary grades.

There needs to be more teachers to teach STEM across the United States. Wright et al. (2019) completed a study to evaluate the status of STEM teachers across the United States. The research proved a shortage crisis is influenced by the lack of new teachers and the high turnover of current teachers. The study showed that current professional development schemes do not adequately prepare teachers for the complexity of the work field, which results in massive dropout and teacher turnover. As a result, the research proposed a new scheme that can develop resilience skills and adaptability to cover the vacancies in the STEM workforce to help retain STEM teachers. Elementary science teachers, in particular, struggle with integrating of STEM as they do not have the necessary background to teach the engineering practices associated with STEM. Lesseig et al. (2016) concluded that teachers value STEM to integrate engineering and promoting for the 21st-century skills in the classroom. Nevertheless, most teachers found implementing the STEM design challenge daunting within a traditional classroom as teachers face pedagogical, curricular, and structural challenges. Smith (2020) showed that teaching engineering is not a common practice across all grades, with 48% of elementary science classes receiving engineering instruction a few times a year and 16% not receiving any engineering instruction.

NGSS has elevated the engineering design and equated it with science inquiry at all grade levels, forcing elementary teachers to create a new interdisciplinary connection to the new engineering content and pedagogy (Rose et al., 2017). All teachers are now expected to teach STEM as mandated by NGSS. Traditional certification programs for in-service teachers do not cover STEM. Elementary teachers are not equipped to teach technology and engineering, so they struggle when implementing STEM. A mixed-method study by Yesilyurt et al. (2021) centered on elementary science preservice teachers ($N = 84$) and explored enhancements in their self-efficacy following a science teaching method course. It showed that the engineering intervention improved teachers' self-efficacy but did not impact their engineering beliefs about teaching outcomes. Rose et al. (2017) conducted a study to identify models of teacher preparation programs that can prepare pre-service teachers to teach engineering and technology in elementary classrooms. The study showed that out of 44 institutes known to prepare engineering and technology teachers, 14 institutes provided learning experiences that can prepare elementary teachers to teach engineering and technology, and only nine offered distinct coursework related to engineering and technology teaching at elementary grades. The study revealed that currently, there are six different models offered to preservice teachers: a course, a concentration of courses, a certification, a minor, a bachelor's degree, and a master's degree. The study concluded that there is a brief window to evaluate the suitability of these programs in preparing teachers with the needed content knowledge and pedagogical experience.

In the Arab world, in general, the situation is more complicated. Teachers have no background in teaching STEM, are used to teaching science and math in isolation, and are not used to creating connections to real-life situations (El-Deghaidy et al., 2017). John and Varghese (2018) directed a study in Dubai to assess the effectiveness of teachers implementing STEM education in classrooms at private schools. The study showed significant gap between what teachers put in their STEM lesson plans and what they deliver in the classroom. While teachers' lesson plans showed the integration of topics and emphasis on real-world applications, their classroom teaching did not provide time for students to develop problem-solving or critical thinking skills. It did not provide continuous assessment opportunities, raising concerns about the quality of STEM education in the classrooms (John & Varghese, 2018). Another mixed-method empirical study by Chaya (2023) focused on STEM elementary teachers in Abu Dhabi, UAE (N = 75), showed that 50% of the teachers find difficulties implementing STEM due to the lack of resources, time, and adequate professional development.

Engineering's Place in the Next Generation Science Standards

Engineering occupies a big chunk of NGSS reform. With the burdensome requirements of developing the engineering design process within NGSS, teachers need more time to cover the standards. National Academies of Sciences, Engineering, and Medicine (2018) confirmed that 41% of kindergarten through Grade 3 classrooms received 20 min of science instruction in some weeks, and almost one-third of 4-6 classrooms received 20 min of instruction less than weekly as the primary focus for elementary teachers is developing language and computational skills. While teachers tend to neglect teaching science to develop math and literacy skills, NGSS requires including engineering in the previously full, limited schedule of teaching science (Dailey, 2017).

Whitworth and Wheeler (2017) explained that engineering and science have different goals; engineers aim solve human needs, while scientists focus on understanding how the natural world works. Teachers need to immerse students in real-world situations that allow them to practice the engineering design processes. Pleasants and Olson (2019) recognized the differences between science and engineering as they conducted a study on teachers to measure their Scope of Engineering (SOP) knowledge. Pleasants and Olson (2019) conducted the study during a professional development project aimed at developing science and engineering instructions by teaming science teachers with engineering graduate students to develop engineering instructions for grades 3-5. The study revealed that many teachers have broad definitions of engineering, placing engineers as problem solvers, but failed to distinguish the jobs that fall under engineering. Thus, the study concluded that teachers do not fully understand what they can consider as engineering.

Dailey (2017) explained that the Engineering Design Process (EDP) is an instructional strategy that science teachers can use to avoid the one-size-fits-all instructions that dominate science education, to engage students in critical thinking and problem-solving situations, and to develop 21^{st}-century skills. EDP involves five steps where students ask, imagine, plan, create, and improve (Dailey, 2017). Kaya et al. (2019) explained that including the EDP in elementary grades can spark students' natural curiosity towards the engineering; however, teachers face two problems: lack of time and lack of confidence in teaching science in general, let alone teaching engineering. They studied 20 preservice elementary teachers enrolled in using EDP through 3D printing projects demonstrated that when teachers have confidence in their engineering-teaching efficacy, they can engage students in engineering challenges that increase achievement (Kaya et al., 2019).

Teaching engineering requires a different mindset than teaching science. A study by Lottero-Perdue and Parry (2017) examined the concept of failure in both engineering and science education. While failure plays a vital role in the EDP as engineers use the failure of design as a learning opportunity and even sometimes design for failures to test safety, teachers avoid failure in education. Lottero-Perdue and Parry (2017) conducted mixed-method research with a survey of elementary teachers (N = 254) new to teaching engineering and an interview with 38 teachers to study their reactions and attitudes toward failure. The study concluded that many teachers have a negative view of failure, which would not allow students to experience failure in their classrooms; many others have an attitude of considering failures as mistakes, and the teachers who have a growth mindset still struggle when trying to encourage resilience and develop growth mindset among students (Lottero-Perdue & Parry, 2017).

Pedagogical Content Knowledge

NGSS calls for teachers to immerse students in authentic scientific inquiry and to integrate technology and engineering within every science classroom at every level. Elementary teachers need more background, knowledge, or experience with such instructional practices and concepts. Shulman (1986) explained that teachers need to possess content knowledge (CK) and pedagogical knowledge (PK) to teach any level or any subject. Content knowledge, or what can be defined as subject matter knowledge, represents teachers' quality, quantity, and organization of concepts and ideas that pertain to the subject of study. In contrast, the PCK represents teachers' instructional practices to make content accessible to students (Yang et al., 2018). Shulman (1986) explains that the central role of PCK is to help teachers convert content knowledge into comprehensible instructions and experiences for students. The subject matter knowledge and PCK are vital factors affecting students' development (Diamond et al., 2014).

PCK is specific to the particular topics within the subject matter. Teachers must have professional knowledge of the details of a topic, such as the prerequisite knowledge required by students, the material and examples needed to teach a concept, and the pedagogical content of the effective methods to be able to successfully plan or teach a lesson (Krepf et al., 2018). Teachers, especially at lower elementary levels, often cite that they do not have the content knowledge necessary to teach science (Smith, 2020; Tuttle et al., 2016). A study conducted by Hammack and Ivey (2017) on elementary teachers to investigate their self-efficacy in teaching engineering practices in an NGSS state in the United States showed that teachers have low engineering self-efficacy and low engineering-PCK which makes it hard for them to teach engineering practices associated with the NGSS. Another mixed-method sequential study by Kaya et al. (2021) centered on secondary science teachers concluded that teachers content knowledge, pedagogical knowledge, and experiences affect their implementation of inquiry practices and self-efficacy in teaching inquiry. The study also showed teachers are more confident using teacher-centered than student-centered inquiry practices.

PCK plays a crucial role in teachers' choice of instruction and practices used to implement the three dimensions of NGSS. Elementary teachers' lack of experience and knowledge of NGSS can risk the implementation of classroom instructions that would not help students develop the necessary science and engineering practices. A study by Merritt et al. (2018) examined how kindergarten and first-grade teachers included NGSS scientific and engineering practices in inquiry-based lessons over a professional development course targeting elementary teachers. The study reflected a lack of PCK that hindered teachers from implementing the practices. The researchers could not observe evidence for teachers engaging students in engineering practices, and there was a lack of incorporation for some practices, such as modeling, constructing explanations, and engaging in arguments from evidence (Merritt et al., 2018). The study showed that many teachers have "narrow views of the scientific practice" and a linear view of "one scientific method" (Merritt et al., 2018, p. 1335). Such views oppose what is required by NGSS by limiting the practices teachers' use in class or the discussions that engage students (Merritt et al., 2018).

Teachers' epistemological orientation affects their choice of instructional practices and practices in the classroom. Suh and Park (2017) conducted a qualitative study of three teachers who implemented argument-based inquiry as an innovative teaching strategy in a student-centered classroom. Their findings highlighted the connection among teachers' epistemological orientation, knowledge bases, and the sustainability of implementing innovative teaching practices after professional development. The study showed that to implement the fundamentals of argumentative inquiry-based practices, teachers need to shift their epistemological orientation to student-centered views. The study also noted that teachers who have aligned views between their epistemological orientation, knowledge of student understanding, and knowledge of instructional practices were able to display paradigmatic changes leading to the implementation of new innovative approaches. Teachers could sustain these practices due to the positive evidence of students' learning. The study concluded by stressing the importance of professional development programs in changing teachers' orientation and allowing them to align their new epistemological views with their awareness of how students understand and what instructional practices can be used.

Professional development support in pedagogy and content is needed to increase teachers' PCK to implement NGSS. Post and Van Der Molen (2020) conducted a quasi-experimental pretest-posttest design focused on six primary school teachers and principals (*N* = 120) to investigate the effect of a training program on teachers' behaviors and attitudes towards inquiry teaching. The study concluded that teachers' self-efficacy and enjoyment in teaching inquiry increased after professional development, yet improvements in teachers' inquiry teaching quality were inconsistent across the treatment groups. The conclusion was mainly because of school factors that hindered improvements—leading to the conclusion that change needs to be conducted at the school level to sustain improvements. Yang et al. (2018) conducted a study to explore the effect of professional development on various teachers' outcomes, including change of knowledge, change of practice, understanding of interdisciplinary science concepts, and effect on students' beliefs. The study concludes that teachers' attitudes and expectations and their support for inquiry positively correlate to students' self-efficacy and teachers' understanding of the nature of science. The research noted that teachers' PCK related to changes in classroom practices is directly linked to the quality of professional development provided. As a result, teachers need a certain amount of professional development to positively affect students' achievement and understanding of the interdisciplinary concepts of science.

Summary and Conclusions

Science education has been under reform for the last decade to elevate science education in the United States and create global competing citizens. Higher dependency on STEM requested significant reforms in science standards and the incorporation of technology and engineering to ignite interest and prepare students for STEM careers. Similar educational restructurings occurred in the UAE as the rulers wanted to move to a competitive knowledge-based economy by developing first-rate education and fostering innovation to achieve international recognition (KHDA, 2017). All these changes lead to the development of new standards that can build science literature students who can compete internationally. These standards extend beyond the United States and are used at International American private schools in the UAE.

The literature presented in the first section of this chapter offered a synopsis of the reforms carried out in the United States, leading to the release of the *Framework for K–12 Science Education* and NGSS and their implication on science education with emphasis on elementary teachers. Similarly, the second section presented the status of the UAE's educational reforms and the current position of science education. The third section included literature that details the distinctiveness of NGSS standards and their impact on science education. Next, the fourth section analyzes the literature on elementary teachers' implementation of NGSS, including the shifts required, their experience with three-dimensional learning, and the incorporation of STEM and engineering. Finally, the fifth section presented literature related to PCK, which forms the framework of this study, showing how PCK affects elementary teachers' choice of practices that can support the implementation of the standards.

Prior literature presented in this study presented the changes required by teachers in their content knowledge and pedagogical choices to implement NGSS successfully. The literature pointed out concerns about the preparedness of elementary teachers to teach engineering practices and STEM topics following the recommendations of NGSS. Similarly, research in the UAE showed that teachers do not have aligned epistemological orientations and pedagogical practices with the requirements of NGSS. This lack of alignment raises questions on the readiness of elementary teachers to choose and implement practices that can develop three-dimensional learning in elementary classrooms in the UAE. Consequently, there is a need for a better view of how elementary teachers use their PCK to teach three-dimensional instructions that can meet the demands of NGSS. Understanding how teachers integrate their content knowledge of the three NGSS dimensions with the pedagogical decisions on which instructional practices can support three-dimensional teaching and learning can increase student attainment and inform professional development needed to help teachers implement NGSS in UAE.

Chapter 1 introduced the goals and objectives of the study. Chapter 2 presented literature review findings that I will use to describe the research methodology in Chapter 3. The following chapter details the factors and rationale for recruiting study participants as well as the setting and context of the study. The chapter includes a thorough narrative of data sources, collection methods, and data analysis that can be used to conduct the study. Finally, the chapter highlights issues related to trustworthiness, including credibility, dependability, and transferability, as well as ethical considerations and limitations.

Chapter 3: Research Method

The literature review in Chapter 2 showed that there is a gap in understanding the preparedness of teachers to implement three-dimensional instructions in the classroom to fulfill the vision of NGSS. NGSS requires teachers to execute significant shifts in their instructional practices to incorporate the three dimensions, including immersing students in real-life situations, scientific inquiry, and engineering design (Castonova & Chenobilsky, 2020; NGSS Lead States, 2013a; Smith, 2020). Research shows that elementary teachers struggle the most as they lack the PCK on how to make NGSS achievable for all students, especially in early grades (Meredith, 2019; Roseman et al., 2017). The goal of this qualitative exploratory study was to explore elementary teachers' readiness to teach NGSS and the instructional practices they use in classrooms to teach three-dimensional standards. The units of study were elementary science teachers in private schools who followed the American curriculum in the UAE.

In this chapter, I discuss the research method that I used to conduct this study. Key sections are devoted to the research design and rationale and the role of the researcher. I explain the methodology, including participant selection and recruitment, instrumentation, and data collection and analysis methods. I also consider validity and ethical issues.

Research Design and Rationale

In this study, I explored how elementary science teachers who currently implement NGSS standards use instructions in teaching the three-dimensional standards. I sought to understand how teachers implement three-dimensional standards and what instructional practices they use to teach NGSS. The two RQs I sought to answer were as follows:

RQ1. How do elementary teachers implement instructional practices that integrate the three dimensions when teaching NGSS at American private schools in the UAE?

RQ2. How do elementary teachers integrate their PCK and curricular knowledge when implementing instructional practices that teach the three-dimensional content of NGSS?

The study was an exploratory qualitative research case study. Ravitch and Carl (2016) explained that the research design should be consistent with the research goals. Exploratory studies help researchers to understand something that is not yet fully known in an exploratory approach (Ravitch & Carl, 2016). In this study, I wanted to create a deeper understanding of how teachers use three-dimensional instructions to integrate the three dimensions of NGSS. The central focus of this study was the set of experiences and perceptions of teachers as they implement NGSS. The rationale for choosing qualitative research was its ability to explore teachers' experiences and attitudes. The reason for choosing a case study was its ability to offer a comprehensive perception of the bounded unit (see Burkholder et al., 2016). Research on NGSS implementation in the UAE was lacking, based on my review of the literature; therefore, this study may further understanding of how teachers in UAE implement new standards. Shulman's (1986) framework of PCK was the theoretical foundation for the study because it illustrates how teachers blend their content knowledge with their knowledge of pedagogical practices to teach three-dimensional NGSS instructions in the science classroom.

I used a case study research design. Case studies involve a detailed analysis of a phenomenon within a real-life context (Burkholder et al., 2016). In line with the requirement of case study data collection, multiple sources are used to collect data for evidence (Yin, 1984). I collected data from three sources to create a full picture of how teachers perceive and implement three-dimensional instructions. It was imperative to allow participating teachers to talk about their experience in implementing three-dimensional instructions in an interview, to watch participants actively implement three-dimensional instructions through classroom observations, and to examine lesson planning documents to understand how participants connect content to practices when delivering three-dimensional instructions.

Role of the Researcher

As is the case with all qualitative research, I was an "observer participant" (Burkholder et al., 2016, p. 82) in this study. As an observer participant, I did not engage with the activities of the participants but was present in the setting as an observer (see Burkholder et al., 2016). I was the chief data collection instrument for this study in interviews, document analysis, and classroom observations. The 10 participants in this study were elementary science teachers who were currently employed at private U.S.-curriculum schools in Dubai, UAE. All participants were full-time employees who taught kindergarten through Grade 6 classes. I might have had previous interactions with the teachers at these schools due to my consultancy work for a private company in the UAE. I also might have provided training for some of these teachers on how to implement an

American-published program. However, I never held any supervisory role or evaluative roles and was not an employee at any of these schools.

Research bias may always exist in qualitative research, as researchers always approach a study with previous experiences and understandings (Patton, 2002). I previously worked as an elementary science educator at a private U.S.- curriculum school then as the head of the science department. During my work as the department head, I tried to implement NGSS upon its release in 2013. My experience as a science educator and head of department provided me with the necessary background to understand NGSS and its implementation in elementary classrooms. My work as a consultant at schools allowed me to interact with various teachers across different schools in the UAE. My background and experience assisted me in gathering and analyzing data. I used a log to document all collected data for constant reflection to avoid researcher bias.

To further minimize personal bias, I developed the interview questions within the conceptual framework and followed an interview protocol. Later, I used codes in analyzing the collected data. I also included data triangulation to ensure the consistency of data. I avoided providing any incentives when choosing the participants. Those who participated did so based on their own will and without any contractual obligation. Participants who contributed to the study had the opportunity to contribute to research on how to better implement NGSS in the UAE.

Methodology

In this section, I provide details on the selection of participants, sampling, instrumentation, recruitment, and data collection methods that were used in this study.

The Participant Selection section includes details on the characteristics of the participants for the study. I also describe the sampling size and technique. The Instrumentation section clarifies how data were collected and how the data collection related to the goals of the research. The section also includes discussion of the recruitment, participation, and data collection and analysis for the study.

Participant Selection

There was only one group of participants in this study: K through 5 elementary science teachers that served as the bounded unit of study (Burkholder et al., 2016). All teachers were current employees in private U.S.-curriculum schools in Dubai, UAE. All chosen teachers had at least 3 years of experience in teaching science. Teachers chosen for this study must have teaching experience as this would allow them to have the required pedagogical knowledge.

I started the recruitment process by visiting the schools implementing NGSS in Dubai and meeting with the principals to acquire permission to conduct the study. I requested the teachers' database. I only considered elementary teachers with at least 3 years of experience from this database. I initiated communication with the teachers once I acquired the principals' permission to conduct the study. I sent teachers an invitation by email to participate in the research study.

Through purposeful sampling, a researcher can decide to select and observe a sample that is demonstrative of the population that will be useful for the study (Babbie, 2017). Ravitch and Carl (2016) explained that qualitative research deliberately chooses purposeful or strategic sampling as the population for the study should have the required experience to respond to the RQs. Purposeful sampling was the right choice for this study, as teachers should have a certain amount of experience in teaching science and implementing NGSS to support the acquisition of responses to the RQs. The majority of the sampling population was from the Emirate of Dubai as teachers in Dubai have been implementing NGSS for a few years now under the requirements of the KHDA.

There is no fixed rule in qualitative research regarding sample size. Qualitative research aims to acquire clear and multi-perspectival understanding, so sampling size becomes less important (Ravitch & Carl, 2016). However, the sample size must be enough and diverse to acquire a deeper understanding of the phenomenon studied. The study recruited 10 teachers who teach elementary classes to offer various perspectives and understanding of the phenomenon studied.

Instrumentation

Case studies use various data from people and other sources (Burkholder et al., 2016). I used three instrumentation methods to achieve the depth of data required to understand the phenomenon. The methods included interviews, observations, and artifact analysis. Using interviews was a powerful way to capture data and build an understanding of teachers' content and pedagogical knowledge used to choose the implementation practices in the classroom. Interviews explore attitudes and feelings, which other forms of instrumentation cannot capture (Lambert, 2012). The choice was to use semi-structured interviews. I prepared the main questions but could still ask further questions and pursue new information based on the interviewee’s responses. There were one-on-one, face-to-face interviews to increase engagement and give teachers the flexibility of time and location. When social distancing issues prevented the face-to-face interviews, I used virtual meetings through Zoom or phone calls to conduct the interviews.

Literature review findings and my experience in dealing with teachers who teach NGSS informed the development of interview questions. The interview questions were developed using a carefully structured interview protocol (see Appendix A) to minimize research bias (Butin, 2010). Interview questions were developed in the four phases of the Interview Protocol Refinement Framework (Castillo-Montoya, 2016). In the first phase, all questions were set and refined through the lens of Shulman's (1986) framework. They aimed to keep a central focus while developing an in-depth understanding of the RQs by exploring teachers' implementation practices and how they utilize PCK. A matrix was developed to align the interview questions to RQs (Castillo-Montoya, 2016). The second checking phase ensured that the interview questions were mainly open-ended to prompt discussions and help the teachers share their perceptions and concerns. In the third phase, the interview questions were checked by a principal, head of department, and the chairman. Feedback was used to strengthen and refine the interview questions. In the last phase, I piloted the interview protocol on two teachers under similar conditions to help further refine the questions before using them in the actual study.

The second data collection method included classroom observations to understand better how participants taught three-dimensional instructions and how they integrated the three dimensions of NGSS within a class session. The choice was for non-participant structured observation methods. In this observation scheme, the non-participant observer watches what is happening without getting involved while precisely knowing what to look for in the classroom (Lambert, 2012). Classroom observations can provide real-life data that would either confirm or contradict the data collected in the interviews (Lambert, 2012). With the permission of teachers and school principals, an in-class observation was conducted for each of the interviewed teachers. I followed an observation protocol (see Appendix B) when attending a classroom session. When observing the lesson, I used the NGSS Lesson Screener (NGSS Lead States, 2016) as a rubric to take notes and to ensure consistency in the observation protocol. Additional descriptive field notes were used to record observations of the instructional practices and reflections on how these practices implement the three-dimensional learning of NGSS. I did not interact with anyone during the observation session. I conferred with the teachers after the observation for feedback.

All teachers prepare lesson plans that specify the standards and the instructional practices that they will use. The researcher analyzed these documents to collect data on teachers' instructional practices to teach three-dimensional standards. Lambert (2012) explains that document analysis can provide factual data regarding the practices used to compare other data collected. Before the classroom observation, the teachers provided a copy of the lesson plan for the observed lesson.

Procedures for Recruitment, Participation, and Data Collection

This study had 30-45 min of face-to-face, one-on-one interviews with the selected teachers. Questions focused on data that reflect the study RQ. Following the interview questions, teachers set a date and time for classroom observation. Before the classroom observation, teachers emailed the lesson plan for the observed session. Throughout this phase, I aligned procedures for recruitment, participation data collection, and analysis to pay constant attention to bias and ensure consistency through academic protocols to increase the trustworthiness of the data (Butin, 2010). The sections below detail the approaches used.

Recruitment

The procedure started by calling the school and scheduling an appointment with the principal to recruit teachers for this study. I needed the principal's approval to operate in any private school in Dubai. The approval included recruiting school teachers and using the school premises for the study. After obtaining the approval, the human resources department at each school provided a list of the elementary science teachers and their emails. The list was filtered to send emails for teachers to participate in the study. The email detailed the target grades and the experience level needed to be able to participate. The invitation also included the goals of the study, details of the data collection, and the expected commitment of the participants. Teachers sent a response with their approval and a confirmation of their teaching grade level and teaching experience. Teachers were also requested to share their details to communicate with them when assigning a suitable time to conduct the interview. The target number of teachers recruited for this study was 10 science teachers at elementary grade levels.

Participation

When the teachers responded with their approval and met the required criteria, the school principals received a complete list of the names chosen. I then sent a follow-up email with the consent form that teachers needed to sign before the interview.. The form included benefits, risks, and options to withdraw from the study. In the same email, the teachers assigned a suitable time and venue for face-to-face interviews. After the interview, the teachers assigned a date and time to conduct classroom observation. The principals received the schedule of the classroom observation for approval. Teachers shared their lesson plans through email on the day before the classroom observation. Teachers were able to pull out of the study at any time before the completion of the interview.

Data Collection

Face-to-face interviews were 30–45 min each and were recorded using a digital voice recorder on a smartphone. During the interviews, camera recorders were not used due to cultural and legal restrictions in the UAE. The teachers stated their preference for conducting the interview on or off campus. If teachers decided to conduct the interview off campus, they provided a location of preference to ensure they were comfortable. Before the interview, teachers received a copy of the interview questions to add any comments or concerns. All the recordings were transferred and stored on a hard drive. Another backup copy was saved on my personal computer protected by a password. After transcribing the interviews, each teacher will receive an email with the transcript to check and approve. The face-to-face interviews might be replaced with a virtual Zoom interview when the COVID-19 social distancing directives were still in effect.

Classroom observations occurred within the school during a lesson period with students. After acquiring the principals approval, the teachers assigned a date and time for the classroom observation. I was present in the classroom during the whole 45-min session. I observed students and teachers through the NGSS lesson. I used a template to record the observations. The recordings were confined to the teachers' practices to develop the three dimensions of NGSS. All logs were kept in a folder along with notes. Teachers emailed their lesson plans in PDF format. The lesson plan served to understand teachers' practices that use and how they link them to the three dimensions of NGSS. I used a reflective journal to document observations from the lesson plans. All lesson plans were safely kept in a secure safe, with observation logs, notes, and a reflective journal. Only I had access to the safe. All documents were scanned and saved on a hard drive as a backup copy. The hard drive was password protected, and only I had access to the password.

Data Analysis Plan

All data collection methods depended on the research design and aligned with the RQs. Shulman's (1986) framework was used to develop provisional codes to analyze the data gathered. I used codes to analyze interview transcripts, field notes from the interview and classroom observations, and lesson plan documents. Saldaña (2016) stated codes must be consistent with the research design. I used descriptive coding for the field notes and lesson planning documents during the first coding cycle. Descriptive coding uses simple codes to summarize data in nouns or short phrases (Saldaña, 2016). Saldaña (2016) revealed that descriptive coding does not give insight into the participants, their perspectives, and their emotions, so it is recommended not to use it on interview transcripts. I used NVivo and process coding to the interview transcripts to obtain the depth of data needed. In coding data, NVivo coding uses verbatim phrases, while process coding uses short verb phrases to summarize data (Saldaña, 2016). I used codes derived from the essential questions to judge whether the data is relevant to the research (Linneberg & Korsgaard, 2019). Codes focused on teachers' instructional practices, their views on implementing three-dimensional learning, and the choice of instructional practices based on teachers' PCK and curricular knowledge.

The first coding cycle started with provisional coding, followed by open coding at the subsequent stage through memos and sorting. The second cycle used a more focused approach to analyze emerging themes. Codes were combined based on common themes, frequent patterns, unique codes, and those that diverged from the expected themes. Codes were classified, combined, themed, and conceptualized to build conclusions and theories (Saldaña, 2016). I used hierarchy maps to create connections between the codes and create themes. When codes were combined, more focused themes emerged, which created opportunities to analyze connections; this allowed for analysis that developed answers to the RQs (Linneberg & Korsgaard, 2019). All transcripts and artifacts were reviewed and recorded to ensure the codes were appropriate to the text and the identified themes. Discrepant data were used to critique and evaluate the findings. Subsequent coding cycles were used until data developed into solid conclusions. All discrepant data were reported along with the conclusion. If I fail to achieve data saturation with the selected sample, more participants are selected until saturation is achieved. Data was run through NVivo software. NVivo analyzes data and looks for trends, themes, and patterns within the data provided. NVivo creates word clouds, word trees, and mind hierarchy maps to sort data. I used the results from NVivo to confirm my manual results and check whether my coding data matched the software's.

Trustworthiness

I put all efforts into promoting dependability, credibility, transferability, and confirmability to ensure the study is high quality. Credibility ensures a match between the data collected and the RQs and serves as the internal validity tool (Burkholder et al., 2016). Procedures to ensure consistency across data instrumentation and data collection methods were well-planned and implemented to guarantee credibility. I followed explicit protocols when collecting data. I carefully followed the participant selection criteria when choosing the participants for the study and used internal validation when conducting the observations and document analysis. I continually documented my thinking and opinions in the reflective journal to monitor personal bias. A professional colleague peer-reviewed all data and findings. The participants performed member checks to ensure the data captured the complete picture. Data were triangulated for consistency through three data instrumentations.

Transferability and dependability are external validity tools. Although qualitative research does not aim at generalizations, the findings should construct meaning beyond the study case (Burkholder et al., 2016). To achieve transferability, I provided thick, rich, and extensive descriptions of the interviews and observations. Choosing teachers from diverse grade levels and multiple schools ensured that the obtained data gave a broad picture and a clearer perception of the phenomenon.

Dependability is the "stability of data" (Ravitch & Carl, 2016, p.189). All the data collection methods should be appropriate and can answer the RQ to secure the dependability of data over time. The data collection methods were sequential, focused, and linked directly to the RQs. Data triangulation of through three different instrumentations played a decisive part in achieving dependability. Using reflexive journal examined any bias or influence over the study, which addressed both dependability and conformability. I carefully scrutinized all data for any variation or abnormality. In addition, using of the reflective journal and the triangulation, selected colleagues externally audited the data collection, data analysis, and findings to address conformability adequately.

Ethical Procedures

I carefully followed all the recommendations of the Office of Standards Research at Walden University to ensure that I conformed to all the ethical standards. The Institutional Review Board approved the study and its methods before conducting it, recruiting the teachers, or collecting data. I called all the principals, briefed them about the study goals and collection and data analysis methods, and obtained their consent. I successfully fulfilled the CITI program courses and adhered to the ethical principles outlined in the *Belmont Report* when conducting the study. Accordingly, teachers received a complete description of the study details and signed a consent letter before initiating the study. Teachers knew they could pull out of the study whenever they wished. The study did not include data that might help identify the participants to assure discretion and anonymity. All participant details, or identifiers were removed from any published data and replaced by pseudonyms when referring to them. Original data sources and materials were safely stored on an encrypted, secure drive.

Summary

This chapter described the research design with a rationale for choosing a qualitative exploratory case study to address the RQs. I intended to understand better how well elementary science teachers who teach at American-curriculum private schools in the UAE are prepared to teach the NGSS by choosing and implementing instructional practices that can intertwine the three dimensions of NGSS. The chapter detailed the instrumentation methods for collecting and recording data and presented the proposed method of data analysis. The methodology and I served the design and objective of the study. The chapter also explained sampling approaches and participant selection criteria while linking them to the research design chosen. The chapter detailed the instrumentation methods for collecting data and recording it and presented the proposed method of data analysis. The chapter also suggested plans to address issues of trustworthiness and all the ethical considerations to ensure that the research is valid and of high-quality.

The following chapter outlines on the study results by outlining the setting and data analysis methods. It includes an explanation of the data analysis procedure and the results. Finally, the chapter highlights issues related to trustworthiness, including credibility, dependability, and transferability.

Chapter 4: Results

I conducted this exploratory qualitative case study to better understand how elementary teachers use pedagogical content and curricular knowledge to implement instructional practices that integrate the three dimensions of NGSS when teaching science at American private schools in the UAE. The study findings highlight the connection between teachers' pedagogical expertise and their implementation of NGSS' three dimensions through their teaching practices. The study also clarifies how teachers' choice of practices can provide support or become a barrier to teaching the three dimensions at private American schools in the UAE. The following RQs were used to better understand teachers' implementation of the NGSS:

RQ1: How do elementary teachers implement instructional practices that integrate the three dimensions when teaching NGSS at American private schools in the UAE?

RQ2: How do elementary teachers integrate their PCK and curricular knowledge when implementing instructional practices that teach the three-dimensional content of NGSS?

I used the RQs to frame the interview questions and related protocols.

In this chapter, I will discuss and present the results of the study. I will start by presenting the context of the study by describing the setting and the demographics of the interviewed participants. I will also discuss how I analyzed the data and identified the emergent findings. Finally, I will detail my steps to enhance trustworthiness and provide rich data to describe the findings.

Setting

All the participants interviewed for this study currently taught science at private American schools in the UAE. I conducted 10 interviews with elementary teachers via Zoom or phone or in person. All 10 interviews were conducted in different settings as per the choosing of the participant and myself. Some interviews were conducted at the schools in empty classrooms or offices, whereas others were conducted when the participants were home in the afternoon. No personal or organizational conditions influenced the participants during the study to guard against skewing of the study's results. All classroom observations were conducted within the school premises. I attended science sessions for eight of the teachers involved in the study. In all the classroom observations, I sat at the back of the class and silently observed the lesson, students, and teachers. I had no interaction with the students or teachers during the session.

Demographics

Each interviewed or observed participant in this study was a kindergarten through Grade 5 elementary science teacher. I conducted the study across four schools in the UAE. The participants' experiences in teaching science and NGSS ranged between 4 to 20 years. Participants had different nationalities. Table 1 shows the demographics of the participants.

Table 1

Participant Demographics

School	**Pseudonym**	**Grade taught**	**Gender**	**Years of experience**	**Country of origin**
1	Mona	5	F	15	Jordan
2	Hana	K	F	13	Egypt

	Shatha	K	F	4	Egypt
	Soha	1	F	7	Tanzania
	Yola	4	F	6	Jordan
3	Ola	2	F	8	Egypt
	Jasmin	1	F	10	India
	Aya	4	F	4	Palestine
	Lina	3	F	14	Lebanon
4	Samar	2	F	20	South Africa

Note. K = kindergarten.

Data Collection

I chose four schools to conduct the study after receiving approval from Walden University's Institutional Review Board (no. 05-26-21-0290946). Convenience sampling is "selecting a sample based on availability" (Burholder et al., 2016, p. 63). In this study, schools' choice was based on location, approval, and access. The schools chosen are within a driving distance and allowed external observers to be present on their premises without complications. These were important factors when I needed to conduct the classroom observation. I emailed the principals of the four schools. I followed up with the principals via phone.

I received permission from all four administrators to contact teachers to invite them to participate in the study. I received the lists of emails and phone numbers for all potential teachers from the science coordinators, principals, or human resources officers. I emailed all the teachers on the lists with a copy of the consent form. When I first sent the consent emails in June 2021, it was too late to receive participants as it was the end of the academic year, and teachers were already occupied with the final exams. Therefore, I had to wait until October 2021 to contact teachers again. I called the principals via phone to extend their approval and emailed the teachers. I received only three emails with the required "I Consent" for participating. I sent further follow-up emails but received no further participants. In October 2022, I contacted all the principals via phone to extend their approval, and I resent another round of emails with the consent forms. I received seven consent emails from additional teachers. The total number of participants was 10 teachers, which was the amount required for the study. Whenever I received a consent form, I contacted the teacher to request a suitable date and time for the interview. Some interviews were conducted via Zoom at a different time than the classroom observations, whereas others were done on the same day as the observations. I arranged for school visits to conduct both interviews and classroom observations. Requests for an interview by phone were accommodated. All classroom observations were conducted on-site.

I used a semistructured interview protocol, with follow-up questions and explanations when needed. The average time of the interview was approximately 15 to 20 min. Adherence to the interview protocol (see Appendix A) ensured that the participants' responses aligned with the RQs and gave insights into teachers' perceptions and implementation of the NGSS Standards. I kept notes during the interviews and highlighted any phrase that stood out. I also provided further explanations or examples for some questions to clarify the meaning of practices. I manually typed the answers in two interviews as the interviewees were uncomfortable with recording their interviews. Some interviews were video recorded, while the others were recorded in audio format. Some were recorded on Zoom, whereas others were recorded on my phone. With three teachers, I did follow-up interviews after the classroom observation to put a context to the choice of practices that were used in the observed lessons.

After finishing the interviews, I converted all MP4 and MP3 files and uploaded them to Rev.com for verbatim transcription. All transcriptions were manually checked for errors and underwent a second round of manual transcription while listening to the audio. Transcriptions were shared with participants for checking before I started coding. None of the participants provided feedback for change. When the transcripts were ready, they were all uploaded to the NVivo coding program as Word documents.

For classroom observations, I used the NGSS Lesson Screener (see Appendix B). Due to Covid-19 restrictions on observing classes with students, I managed to observe only eight of the 10 teachers in the study. I created a copy of the screener for every teacher and labeled it with the pseudonym. I attended the classes from the beginning of the session until the end of it. The sessions ranged between 45 to 60 min depending on the grade level and school. I joined all classes as an observer without interacting with the students or teachers. As I was observing, I was taking notes on the NGSS Lesson Screener and noting down the practices that were used in the classroom. I also noted the activities that were used to cover the standards. Some lesson plans were shared before the classroom observation, which allowed me to crosscheck the standards with the in-class practices that the teachers used to cover them. In two other situations where the lesson plans were not shared prior to the classroom observation, teachers emailed them or handed them to me when the class session was done. I also conducted follow-up interviews with three teachers to ask about their choice of practices and to better understand how they implemented the NGSS standards.

Data Analysis

I used a qualitative exploratory case study approach to understand how elementary teachers use pedagogical content and curricular knowledge to choose instructional practices that can cover the three dimensions of NGSS when teaching science at American private schools in the UAE. The data underwent multiple cycles of coding and recoding. All interview transcripts were uploaded to NVivo to make it easier to code them. The first coding cycle started with provisional coding derived from Shulman's (1986) PCK framework and the RQs. During the first cycle of coding, I started coding the interview transcripts. The transcripts underwent multiple rounds of recoding. First, each transcript was coded separately. Then, codes were matched and categorized using the answers to similar questions. Open codes replaced provisional codes (see Appendix C for a list of the open codes). I used NVivo to organize data by adding verbatim phrases to the existing codes, generating new codes, or adding code relationships through notes. The codes were consistently matched to the RQs as the coding process continued.

The second cycle was more focused on finding and analyzing themes. Codes were combined based on patterns to build conclusions and theories (Saldaña, 2016). Codes were first categorized as they were combined. The categories allowed for the development of the first three themes. After coding the transcripts, I started coding the lesson plans and the class observations. A similar process was applied as the codes were categorized and linked to the RQs and Shulman's (1986) PCK framework. This coding process led to the development of the fourth theme. All transcripts and artifacts were reviewed and recorded to ensure the codes were appropriate to the text and the identified themes.

Results

This exploratory qualitative case study aims to understand better how elementary teachers use their PCK and curricular knowledge to choose and implement instructional practices to teach the three dimensions of NGSS at American private schools in the UAE. The results of this study can improve understanding of how well teachers can choose and implement teaching practices that integrate the three dimensions of NGSS. The 10 participants provided their perception of the instructional practices covering the three-dimensional standards and how they chose them based on their curricular and pedagogical knowledge.

RQ1: How do elementary teachers implement instructional practices that integrate the three dimensions when teaching NGSS at American private schools in the UAE?

RQ2: How do elementary teachers integrate their PCK and curricular knowledge when implementing instructional practices that teach the three-dimensional content of NGSS?

The participant' abilities to integrate PCK and curricular knowledge emerged through their personal experience and choice of practices. Their coverage of the three-dimensional nature of the standards within their choice of practices was understood through classroom observations. I used qualitative coding to analyze participant' responses to the RQs. The codes and themes are represented in Table 2. Based on the data, four themes emerged: (a) teachers' positive perception of NGSS, (b) positive changes in teaching, (c) integrating PCK with curricular knowledge, and (d) disconnection between teachers' perception of implementing the standards and the actual implementation of NGSS. Table 2 illustrates the codes, categories, and themes.

Table 2

Codes, Categories, and Themes

Theme	Category	Code
Teacher's positive perception of implementing NGSS	Positive perceptions of NGSS	3-5 years of experience More than 5 years of experience Three-dimensional standards Focus on inquiry
	Challenges of teaching NGSS	Student levels Lack of resources to teach NGSS Need more time to teach the standards
Positives changes in teaching science	New ways of teaching science	Teaching engineering Teaching new content Using the 5E model of instructions Using cross curricular connections
	Student-centered classrooms	Students develop knowledge Students develop practices Exploring science Requires innovation
Integrating pedagogical content knowledge with curricular knowledge	Pedagogical content knowledge	Linking practices to content No new topics New content Engineering Teaching earth and space Teaching biomimicry
	Choice of practices	Simplifying Hands-on Investigations Modeling Project-based learning Developing critical thinking Reflection Explorations

Theme	Category	Code
	Choice of resources	Use of external websites Use of teacher guide Use of visuals Use of worksheets Doing research
Disconnection between teacher's perception of implementing the standards and the actual implementation of NGSS	Developing the three dimensions	No authentic phenomenon to drive the lesson Students do not make sense of the phenomenon Developing DCIs only Lack of CCC development Mismatch between the standards, content, and practices

Note. NGSS = Next Generation Science Standards; 5E = engage, explore, explain, extend, and evaluate model; DCIs = Disciplinary Core Ideas; CCC = Crosscutting Concepts.

Data from the interview questions gave me a deep understanding of the teachers' choice of practices based on their curricular knowledge and PCK. These data were cross-referenced with the classroom observations and the lesson plans to understand better the coverage of the NGSS standards in the classroom. From the data, I was able to generate four prevailing themes that are detailed in this section. The description considers the frequency of the participants' responses and their experience in implementing NGSS. The data also reference the classroom observation notes and lesson plans the participating teachers prepared.

Theme 1: Positive Perceptions of Implementing the Next Generation Science Standards

All 10 interviewed participants were comfortable using and implementing the NGSS. They could describe the nature of the standards, the changes in teaching science that accompanied the new standard's vision, and the new content that they will teach. Their expertise in teaching science equipped them with the content and pedagogical knowledge to feel at ease when planning for the new standards. Only a few participants cited challenges using the NGSS. These challenges included a lack of resources, low English-speaking levels among students, and lack of time. These challenges were more related to school systems than teacher's comfort level with the implementation process. The lesson plans and classroom observations showed that teachers are comfortable planning and implementing activities and practices they felt covered the new standards. The subthemes include details on the participants' perception of NGSS and the challenges they cited when implementing the standards. The first subsection covers their perception and comfort level in teaching NGSS, which stems from their description of the standards and connects to their experience in teaching science in general and NGSS in particular.

Positive Perceptions of NGSS

All participants had a long experience with teaching NGSS. Seven teachers had more than 5 years of experience in teaching NGSS, and three teachers had more than 3 years of experience. All participants were knowledgeable and confident in their ability to teach NGSS. When asked to describe the NGSS, all participants agreed that the standards provide a good framework for setting expectations on what to teach and how to teach science. For example, Shatha explained that "it is a good framework to help us understand what children need in science."

In contrast, Hana explained that "[the standards] specify what pupils must exhibit to be judged proficient for their grade level." Most participants agreed that the changes help students develop better inquiry skills. For example, Hana stated that the standards changed the way students learn science as "they really developed the skills of the students; how to explore, how to investigate, how to discuss and how to learn about science in a different way," Mona also remarked:

> They create opportunities for the students to act not only like scientists, also like engineers. So, they work on both fields, working like a scientist and working like engineers. We have great emphasis on hands-on activities, and the most important thing it is focused on real world phenomena. It's connected to the real world more than the standards we taught before.

Yola commented that the standards help students think like scientists by stating, "They help students to learn how to think and draw conclusions based on evidence." When describing NGSS, four participants referenced the three-dimensional structure of the standards. For example, Hala stated, "The Next Generation Science Standards (NGSS) differ from previous science standards in that they incorporate three dimensions within each standard and have purposeful cross-standard links." Mona focused that "they have three dimensional, which provides contents, techniques, and actions. Content through the disciplinary core idea, techniques through the crosscutting concepts, and we can say actions through the science and engineering practices."

Overall, teachers felt comfortable implementing NGSS and had aligned beliefs with NGSS. Nevertheless, few teachers cited some challenges in the implementation process, such as time and resources. The second subtheme covers the challenges of teaching NGSS. These challenges revolve around teaching NGSS to a particular population, lack of time, and lack of resources.

Challenges of Teaching NGSS

Four participants felt that teaching NGSS is combined with some challenges. Two participants cited that the NGSS standards are not designed for ELL students. Soha stated that the standards "do not match our students, especially those that do not have English as a first language." Shatha remarked that "it is too broad for ELL learners." Two participants stated that their primary concern with NGSS is the lack of teaching time. Hana stated, "To be honest with you, we do not practice 50% of what should be done in science because we do not have time." She continued, "The main problem is the lack of time." Mona stated what she lacked in her science teaching, "[The problem is] lack of time. Implementing NGSS and teaching NGSS standards is really challenging. We need time. I am not giving them enough time." Other teachers felt they lacked resources. Mona said she is concerned about the "lack of equipment and tools." Shatha stated they lack "classroom resources, like when we did matter, we did not have test tubes and containers, so I had to borrow from other classes." When asked what is lacking in her science teaching, Lina stated that "additional access to science resources is necessary and needed."

Theme 2: Positive Changes in Teaching

The second theme of positive changes in teaching is directly linked to the first theme of teachers' positive perceptions of implementing NGSS —the participants' positive view of the standards connected with their classroom practices. NGSS changed how participants set up their science classrooms to become more inquiry-based and student-centered. This change in setup has promoted an overall positive change in teaching science. Participants could express what they felt were the pedagogical content changes that NGSS carried and how they delt with them. How participants dealt with pedagogical changes was best understood by combining their curricular knowledge with their PCK as they taught, according to NGSS. All participants were aware of the changes the standards have brought to teaching science. They cited that NGSS required them to create student-centered classrooms with lots of hands-on, inquiry, and engineering opportunities for students to make sense of scientific concepts and problems. Such teaching changes were evident in how they prepared their lesson plans and delivered the instructions. Overall, participants indicated that they did not struggle with teaching new content.

The theme of positive changes in teaching contained two subthemes. The first subtheme covers participants' perceptions of the new ways of teaching NGSS, which includes using explorations, adding inquiry activities, creating cross-curricular links, and using the 5E instructional model.

New Ways of Teaching Science

All participants felt that NGSS has changed the way that they teach science. Participants noted that they focus more on explorations, inquiry, and practices. For example, Yola stated, "I am guiding the students how to think and find the information rather than giving them the information." At the same time, Lina noted that "[using] inquiry-based teaching assists students in developing the knowledge and skills needed to effectively acquire scientific ideas." Aya echoed, "to provide a new and effective way to teach science through enhancing inquiry opportunities." Hana stated the change was "implementing this in a way that the students can learn more through practicing." Jasmin stated her NGSS change was to "involve students in making sense of natural events and the science ideas underlying them."

Moreover, two participants noted using more cross-curricular links, as NGSS is linked to ELA and Mathematics CCSS. Samar and Shatha stated that they use more connections to ELA and math. Samar also believed that she required students to "create and innovate something" using the "5E Instructional Model" in her teaching.

The observations and lesson plans (see Figures 1 and 2) matched the points the teachers raised in the interviews. All the sessions were fully hands-on with explorations and sense-making. Teachers' explanation time was minimal when compared to students' investigation time. All students in the observed sessions actively practiced science rather than being passive listeners. The lesson plan examples in Figures 1 and 2 show the engaging hands-on explorations; engage, explore, explain, extend, and evaluate (5E) instructional model; visuals used; and cross-curricular connections.

Figure 1

Example 1 of Lesson Plan

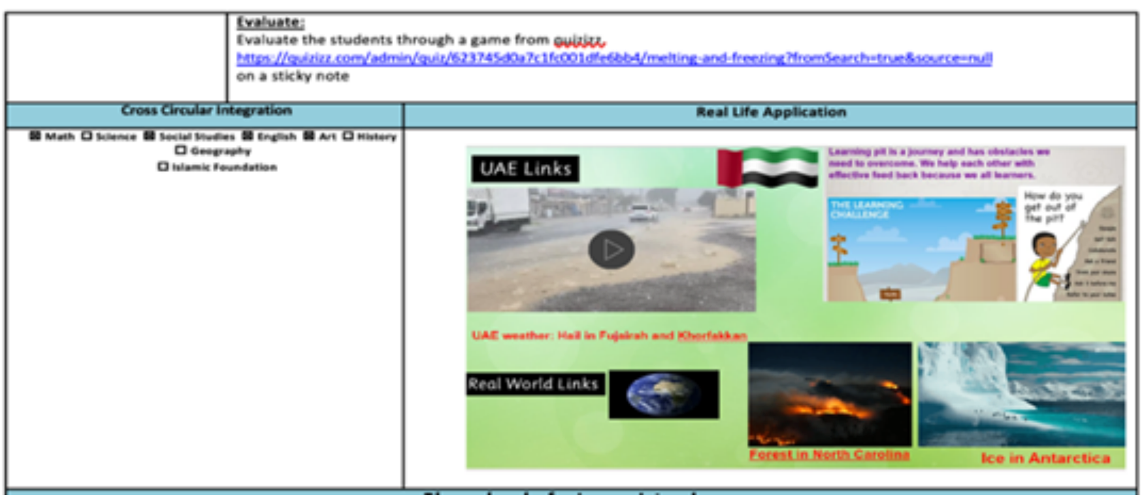


Figure 2

Example 2 of Lesson Plan

Stage 3 – Learning Plan - Key Learning Events and Instruction Period 1			
Lesson Segments	Description of the Instructional Strategies/Tasks/Activities	Teaching/Learning Resources	Estimated Time
Lesson Opening Brief Overview of Lesson:	ENGAGE Sharing the standards, Learning objectives, terminology, essential question A warm-up Activity Students will watch a video about different types of weather. Students will practice the lesson's vocabulary. Claim What is the best weather for playing in a puddle? Task: Students have a trip and don't know what to wear if the weather changes. Can the meteorologist help them?	https://www.youtube.com/watch?v=lGcVzu4GOr0&ab_channel=NGScience	7 min
During the Lesson	EXPLORE + EXPLAIN + ELABORATE Question: What is the weather? Weather is how it feels and looks outside. Diff. Task: Students will make a windsock and test it. AL: Students will make a video reporting todays weather. https://app.seesaw.me/pages/shared_activity?prompt_id=prompt.1ad04fd8-4de8-4736-bbda-814eb427c6f5&share_token=W3WDDITuTh6gjWNv-c_YWg OL: Students will compare a tornado to a blizzard. https://app.seesaw.me/pages/shared_activity?prompt_id=prompt.f05d7495-1b00-4d10-9d70-e20865337929&share_token=wOwF8eh7STSCghR3LpdLZQ BL & Tier: Students will watch the video of a read aloud story then answer about a snowy day. https://app.seesaw.me/pages/shared_activity?prompt_id=prompt.d636820a-b5b9-4374-83ea-ca699c447d76&share_token=tESYacvaQuKuJNCx2GHGYA		30 min
Lesson Closing	EVALUATE Exit Question: Why is it important to learn about weather?		

The second subtheme of student-centered classrooms is a positive outcome of the new ways of teaching science. New ways of teaching science promoted more student-centered classrooms where students are at the heart of the learning process. The theme covers the use of student-centered strategies, usage of activity centers with rotations and cooperative learning strategies.

Student-Centered Classrooms

All participants believed that NGSS focuses on student experience and helps create student-centered classrooms. Hana stated that students "think more, can discuss more about science, what they have learned, explain what they have learned." Mona stated,

> Before, we used to guide them through the inquiries, even if it is independent, we used to provide them with some procedures and hints and so on. But now, we are providing them just with materials, and they plan their own investigations. So, we are leading the students to use their skills or the practices.

Shatha affirmed, "I take them outside more to explore because NGSS-related topics in science." Samar cited that the new standards are "child-oriented." At the same time, Jasmin stated that NGSS requires teachers to "actively engage students in wondering and figuring out science phenomena around them and how they happen."

The lesson plans and classroom observations confirmed the changes and the student-centered approaches used (see Figures 3–5). All the observed lessons were highly engaging for students. Six teachers used stations in the classrooms where students rotated and performed different activities related to the topic being taught. All teachers used cooperative learning strategies and reflection methods. Two observed lessons were hands-on investigation sessions, one conducted in a science lab. All lesson plans included cross-curricular links and ample hands-on exploration opportunities. The lesson plan examples in Figures 3 and 4 show the student-centered activities and stations the participants used to teach the standards. The snippet from the lesson observation summary in Figure 5 confirms that participants are creating interactive inquiry-based student-centered sessions.

Figure 3

Example 3 of Lesson Plan

RESOURCES	- *Crayons* Science Book
TECHNOLOGY	YouTube Videos / Inspire Science videos iPad activities for science Projectables (PPT, songs, videos)
WARM-UP (5 mins):	Ask the Discover the Phenomenon question: Why are there so many plastic bottles? This connects to the module big idea. Ask students to describe what they see and discuss prompts. Interactive presentation (Protect Earth).
CIRCLE TIME (HOOK)-(15-20 mins):	- *Go Online: Check out 'We Recycle'. Watch the animation. Describe what you see.* - Help students turn their observations from the video into questions and discussion prompts: - **Why did the children collect the plastic?** - **What will the plastic be used for?** - **What other materials can you recycle?** **Conscious Discipline of your choice** Butterfly breathing strategy or any class management technique of your choice.
GROUP WORK (20 mins):	**According to readiness groups (homogeneous) or you can distribute sts heterogeneously:** • Students will draw items that can be reused. • Hands-on: Students will design a new object/toll using previously used materials that can perform a task. **AL:** Ask students to explain what they think happens to garbage taken from their homes or the school. Have them draw a picture of where they think it goes. **OL:** On the board, display a landfill and a photograph of a recycling bin. Ask children to provide a list of words that come to mind and write them on board. **BL:** Help students research where local garbage is taken. Ask students to share their ideas of what it might be like to live near a landfill.
REAL LIFE APPLICATION:	Students will understand that humans impact Earth's system, but there are solutions to reduce that impact and help save natural resources.
SOCIAL EMOTIONAL LEARNING:	Student partners will discuss how and why do people help to protect Earth? Then they will report to the group using the sentence frame, ----------help to protect Earth because ------------.

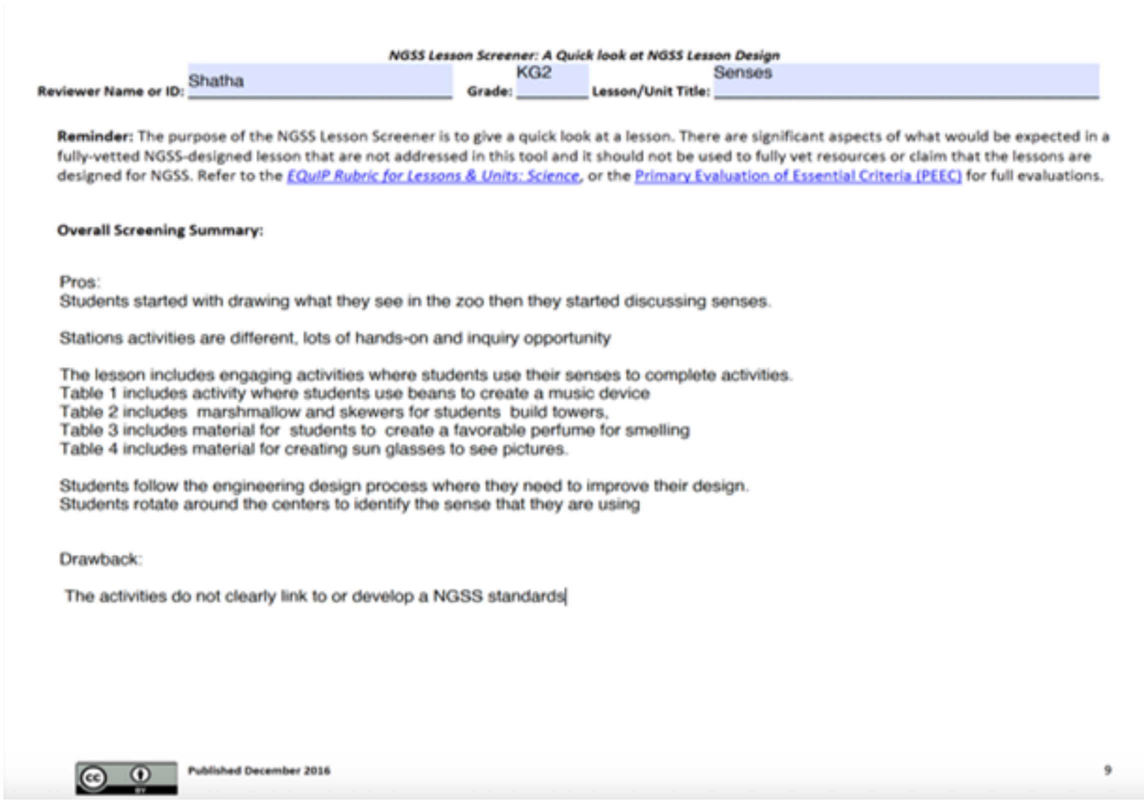
Figure 4

Example 4 of Lesson Plan

RESOURCES	iPad Paper Colors Pencils
TECHNOLOGY	iPad activities Projectables (songs, videos)
WARM-UP (HOOK) - (5 mins):	Breathing Exercises (smell the flowers/blow the candle) Picture questions
CIRCLE TIME (10 mins):	• Draw what they can here, see, touch, smell, taste in different settings. • Ask what parts of the body we use for each action. • When we do each action, what sense are we using? • Senses song
GROUP WORK (20 mins):	Differentiated according to readiness groups (homogeneous) or you can distribute sts heterogeneously: (choice activities to foster different learning styles/preferences/intelligences) • **Centre 1 Noise Makers: Lentils, cups, plates, tape** • **Centre 2 Marshmallow Construction: Marshmallows, skewers, templates** • **Centre 3 Sunglasses: Sunglasses template, laminated circles, markers** • **Centre 4: Perfume Factory: Scented water, cups, bottles**
REAL-LIFE APPLICATION:	Connecting the activities to real-life instances of using sunglasses, hearing music, using/buying perfume.
SOCIAL-EMOTIONAL LEARNING:	Ask the students to bring different objects from the house to describe how they feel in the class. Working in pairs, students will be able to ask their partners questions about a problem (e.g. What, How, Why... etc.) and share their ideas with the class.(While sitting socially distanced).
ASSESSMENT:	Six Facets of Understanding:

Figure 5

Example of Observation Form



NGSS Lesson Screener: A Quick look at NGSS Lesson Design

Reviewer Name or ID: Shatha **Grade:** KG2 **Lesson/Unit Title:** Senses

Reminder: The purpose of the NGSS Lesson Screener is to give a quick look at a lesson. There are significant aspects of what would be expected in a fully-vetted NGSS-designed lesson that are not addressed in this tool and it should not be used to fully vet resources or claim that the lessons are designed for NGSS. Refer to the *EQuIP Rubric for Lessons & Units: Science*, or the Primary Evaluation of Essential Criteria (PEEC) for full evaluations.

Overall Screening Summary:

Pros:
Students started with drawing what they see in the zoo then they started discussing senses.

Stations activities are different, lots of hands-on and inquiry opportunity

The lesson includes engaging activities where students use their senses to complete activities.
Table 1 includes activity where students use beans to create a music device
Table 2 includes marshmallow and skewers for students build towers.
Table 3 includes material for students to create a favorable perfume for smelling
Table 4 includes material for creating sun glasses to see pictures.

Students follow the engineering design process where they need to improve their design.
Students rotate around the centers to identify the sense that they are using

Drawback:

The activities do not clearly link to or develop a NGSS standards

Published December 2016 9

Theme 3: Integration of Pedagogical Content Knowledge With Curricular Knowledge

The third theme explains how teachers integrate their PCK with curricular knowledge to choose practices and resources that can create a student-centered learning experience. The theme is divided into three subthemes that explain participants' pedagogical knowledge, their choice of practices, and their choice of resources. The participants' comfort with the standards and the changes they brought into the classrooms shaped their way of choosing practices and resources. Four out of 10 participants cited that the content of the standards was well-known to them. The other participants cited one unfamiliar topic they did not teach before NGSS. Hana felt it is not the topic that is new, but the way that she is teaching it, "I think teaching about … matter. Matter like liquids and solids. All the topic that talks about matter in general, it was more simple."

Participants' familiarity with the content helped them choose practices they felt fit for their teaching. Their content and curricular knowledge, along with the changes mandated by NGSS, framed how they design their classrooms. Their choice of practices was specific to the domain they were teaching. They also relied on the guidance of an implemented program and did research to get resources and ideas. When choosing their resources, 6 participants cited that they do lots of research and use external websites. This was evident in the lesson plans and classroom observations. The lesson plans and classroom observations confirmed participants' choice of practices but showed a discrepancy between the practices required by the NGSS and those covered in the classroom. There was no clear connection on how the practices create a three-dimensional learning experience for the children.

The theme is divided into three subthemes of PCK, reasons for choosing practices, and choice of resources. The first subtheme covers participants' comfort level with the content that they are teaching, then explains what they considered as new content that was proposed by the NGSS. The theme also covers how they prepared themselves to teach any new content that is not familiar to them.

Pedagogical Content Knowledge

Five out of 10 participants felt that NGSS did not propose teaching content unfamiliar to them and, therefore, had no content-related concerns. Yola stated, "I know all the topics from before as I have long experience teaching science." Aya, Jasmin, and Ola noted that "no new topics" existed for them. Other teachers cited that NGSS added some unfamiliar content. Samar noted that teaching engineering design and technology was new to her. Both Mona and Soha noted that they were required to teach Biomimicry. Hana cited that NGSS required her to teach severe weather for the first time at her grade level. Lina said that NGSS required her to teach space and weather for the first time.

When required to teach new topics, teachers said they did lots of web research and group planning to develop resources and activities to fit the new content. They stated that overall, they always devised strategies to teach the new concepts to the students. When devising these strategies, teachers relied on their expertise in teaching the different domains of science to come up with the right practices. The second subtheme covers the reasons that teachers cited for choosing particular practices. The reasons cited include their knowledge of the domains of science, their student levels and personal preference of particular practices.

Choice of Practices

All the participants felt that they are well knowledgeable about the practices and were able to choose practices that fit the content taught. They were confident that not all practices fit to teach the different domains of science. Mona stated when asked about specific examples, "Some strategies are used in all classes as routine, but I also add strategies to each lesson according to the topic." Jasmin specified, "For teaching life sciences, [students] will not do experiments; they do worksheets." Aya stated, "[For] earth and space science, not all the topics can be investigated in the lab." Shatha stated, "Certain things will not work on senses topic as it is not a project but just hands-on learning."

The participants' choice of practices was linked to the content of the study as well as the level of students. For example, Mona stated that she "will not start in the early stages with argument and evidence. So, [she] develops it step by step based on their abilities, based on their capabilities". Yola said that she "decides [on the practices] based on the topic itself and the abilities of the students. [She] finds different activities and hands-on to implement in the class to make it easier to understand the new topic." Hana noted that she relied on simplifying the content and standards to cater to the ELL population; "Sometimes I have students that really need more simplification, so I use visual, videos or flashcards or make it simpler for them."

Some teachers could instantly point out their choice of best practices. For example, Jasmin, Soha, Shatha, and Samar specified "hands-on." Samar also added "creating models." Aya and Lina said "investigations, experiments, and explorations." Samar also cited "hands-on investigation" and added "creating models."

The third subtheme explains participants' choice of resources to teach the curriculum. All participants relied on a commercially available teachers' guide as the main resource for teaching instructions. Even with the availability or a commercially ready curriculum, teachers still relied on external websites to obtain additional visuals, worksheets, or activities that can enrich students' experience.

Choice of Resources

Most participants used a ready-published teacher's guide to teach the NGSS. Some teachers followed it as it is designed without modifications. For example, Hana said, "I follow the teacher edition. It is the main thing we follow when teaching science," she continued, "Mostly the teacher edition is my guide." Samar also commented, "We follow the textbook… actually it's all there in the teacher guide… read the teacher's guide and you just follow what they tell you." Mona stated, "I look at the teacher edition in our curriculum, in our books… it's helpful." Participants also researched other resources online for extra support. For example, Hana noted that she used "videos like YouTube, we google Teacher Pay Teacher for some resources, teacher resources." Shatha also did the same, "Research, lots and lots of Eduction.com, Teachers Pay Teachers, Pinterest, Teachagram, Teachers for Good Lesson, and [she does] a lot of buying of material." Lina's research involved "visiting many websites to learn more about the topic." Soha also used "one video per lesson, so I have to go through YouTube and Generation Genius."

Theme 4: Disconnection Between Perceptions of Implementing the Next Generation Science Standards and the Actual Implementation

The fourth theme triangulates data between what teachers felt they were doing and the requirements of the NGSS standards. Overall, there was a noticeable improvement in the usage of student-centered practices in the classroom. Participants were relying on their pedagogical content and curricular knowledge to implement the standards; however, classroom observations and lesson plans show a disconnection between the implementation and the coverage of the three-dimensional standards. Participants' comfort with the standards and their expertise did not translate into the proper choice of practices or coverage of the standards. In some classes, there was a clear mismatch between the choice of practices, coverage of content and the standards' requirements. For example, Soha's class was introducing the topic of severe weather while the standard chosen did not include any reference to teaching weather. In Shatha's class, students were learning about senses while the DCI of the standard did not reference senses. In Yola's class, the students were modeling the respiratory system, but the standard did not require that they learn parts of the body systems.

In the follow-up interviews, I asked the participants about their choice of activities and practices and how it links to the three dimensions of the standard. The participants were not aware that they weren't covering the standards and they cited that they were following the lessons as they were outlined in their teacher's guides. In their perception, they were preparing hands-on inquiry activities that fit the requirements of the used program, but these activities did not match the standards. The subtheme shows the lack of three-dimensional teaching. This includes developing the wrong SEPs or DCIs, lack of CCC coverage, and not using phenomena to drive the instructions.

Lack of Three-Dimensional Teaching

In all observed classes, the participants were aware of the three-dimensional nature of the standards and the standards were clearly stated in the lesson plans. For example, when asked about developing three dimensions, Yola’s reply was, "Starting with a phenomenon then ask the students about it. Using crosscutting concepts. Engage students in engineering practices." The lesson observation noticed lack of presenting a phenomenon to drive sense making, the use of a very structured modeling activity, and no development for the CCC. Similarly, Hana cited that "The Next Generation Science Standards (NGSS) differ from previous science standards in that they incorporate three dimensions within each standard and have purposeful cross-standard links." The classroom observation did not show the development of any CCC throughout the lesson.

While the classes were highly engaging and student-centered, most of the chosen activities did not aim at developing the three dimensions. The lessons were student-centered and engaging, with opportunities for students to share ideas and reflect. However, the activities were not developed with three-dimensional standards in mind. At best, the activities were developing SEPs or DCIs in isolation. Most lessons were content-driven, and the activities were set to help learn about a science concept. There was a clear lack of developing CCC in most of the lessons. Students did not make sense of a natural phenomenon or develop broader thinking using the crosscutting concepts as required by NGSS. They mainly learned DCIs or practiced SEPs in stations and centers. In some instances, these dimensions did not fit together. The lesson plan examples in Figures 6 and 7 show a discrepancy between the standard, its dimensions, and what is being taught content in the lesson.

Figure 6

Example 5 of Lesson Plan

Lesson Essentials	Description
Alignment with NGSS Standards	4-LS1 From Molecules to Organisms: Structures and Processes. 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. DCI LS1.A: Structure and Function SEP.7 Engaging in Argument from Evidence: Construct an argument with evidence ,data and/or a model. CCC.4. System and system models.
Chapter Big Idea	Students will relate the structures in the Circulatory and Respiratory systems to their function.
Learning Outcomes	1. Use evidence to evaluate a claim about the Circulatory and Respiratory systems. 2. Compare and contrast between the veins and arteries. 3. Construct an argument and support it with evidence, data, and a model. 4. Relate the organs of the circulatory ad respiratory systems to their functions.

Figure 7

Example 6 of Lesson Plan

Stage 1 – Desired Results	
Standard(s) to be addressed in this lesson:	**K-2-ETS1-2** Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps its function as needed to solve a given problem. **EST1.B Developing Possible Solutions** Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. **SEP.3:** Planning and carrying out investigation. **CCC.1 Patterns:** Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.
Essential Question(s) addressed in this lesson:	Which way is the wind blowing?
Lesson Objectives: (Content + Skills)	**Day 1: I can explain the weather.** **Day 2: I can design a product that predicts the weather.** **SEL: I can work and collaborate with others.**
Prerequisite Knowledge/Skills:	Students understand the different kinds of weather.
Academic Vocabulary/Terminology	weather, thermometer, rain gauge, tornado, blizzard, anemometer

The lesson introduction of most lessons lacked the usage of a phenomenon. Shatha's lesson started with an introductory drawing activity and stations where students explored the senses. Lina's lesson started with a quiz to go over the concepts taught in the lesson. In Omnia's session, a phenomenon was used as the teacher started with a video of melting. However, the phenomenon was used to hook the students, and the probing questions were for the students to get to the correct answer.

Evidence of Trustworthiness

To maintain the trustworthiness of the data collected, I had to consider the areas of dependability, credibility, transferability, and confirmability (Rubin & Rubin, 2012). I addressed each area to ensure that the data collection and analysis is of high level.

Credibility

Credibility in qualitative research is an internal validity tool (Ravitch & Carl, 2016). I maintained credibility by ensuring data represents the participants' comments and views through verbatim transcription and member checking. All the interviews followed a semi-structured protocol with the same set of questions. When the interviews were done, I provided the teachers with a verbatim copy of the interview questions for checking and editing. I also followed the same procedure when doing the classroom observations. All classroom observations followed the same screening procedure and used the same screening document. A summary of the screening document was shared with the teachers. All along, I kept a reflective journal and documented my remarks. Data triangulation helped me put perspectives to all the different results. I also ensured that I reached data saturation. Ravitch and Carl (2016) explain data saturation as reaching the point where the data does not produce new meanings. With my interviews, data saturation was obtained by the fifth interview. In the last five interviews, the teachers' responses were very similar and there was no discrepant case within the data.

Transferability

Qualitative research can be transferable to other contexts through "having detailed descriptions of the data themselves as well as the context (also called thick description) so that the readers/research audience can make comparisons to other contexts based on as much information as possible" (Guba, 1981, as cited in Ravitch & Karl, 2016, p. 189). With the study being confined to a particular geographical region with specific student and teacher demographics, transferability to other regions in other geographic locations with similar demographic populations might be possible. This study is set in an international classroom setting at private American schools where students and teachers are of different backgrounds and nationalities. Participants have at least 3 years of experience in teaching NGSS. All students and teachers are bilingual, with English being the medium of instruction at the schools. Generalizing this study to a similar educational setting is possible. Researchers need to consider the parameters of transferability when applying the study to other geographic locations or with different demographics.

Dependability

According to Ravitch and Carl (2016), dependability is data consistency, showing how data was collected and how it relates to answering the RQs. To ensure dependability, I kept a consistent procedure in collecting data and used data triangulation through interviews, classroom observation, and lesson plan documents to help answer the RQs.

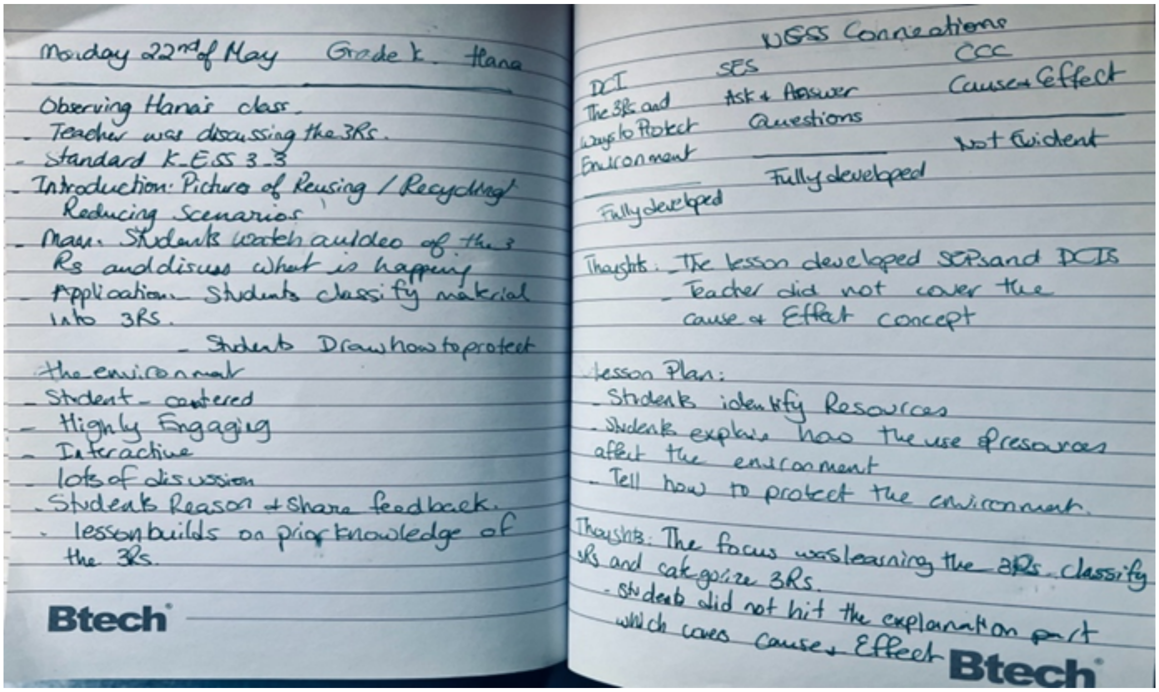
Using the same set of questions and applying a semi-structured protocol allowed me to align the interview data with the RQs. Using a consistent NGSS Lesson Screener enabled me to focus my observations within the lessons on areas relevant to my RQs. The lesson plan documents linked the classroom observations with the standards and choice of practices, triangulating this data with the information gathered from the interviews.

Confirmability

Confirmability is to be able to objectively interpret the data acquired. It can be achieved through triangulation, research reflexivity, and external auditing (Ravitch & Carl, 2016). Throughout the data collection process, I kept notes in a reflexive journal to consistently monitor any bias I had over the study data or findings (see Figure 8). As a current educational consultant who trains teachers and as a former educator who taught science for a long time, I constantly monitored my interpretations of the data through peer debriefings and checks to make sure that an external auditing review confirms my findings and that my personal experience is not reflecting on the results, triangulating data assisted in considering the teachers' perspectives and then evaluating their choice of practices for the three-dimensional standards taught.

Figure 8

Example of the Researcher's Reflexive Journal



Monday 22nd of May Grade K Hana

Observing Hana's class.
- Teacher was discussing the 3Rs.
- Standard K-ESS 3-3
- Introduction: Picture of Reusing / Recycling / Reducing Scenarios
- Main. Students watch a video of the 3 Rs and discuss what is happening
- Application. Students classify material into 3Rs.
- Students Draw how to protect the environment
- Student-centered
- Highly Engaging
- Interactive
- lots of discussion
- Students Reason + Share feedback.
- lesson builds on prior knowledge of the 3Rs.

Btech

NGSS Connections

DCI	SEPs	CCC
The 3Rs and ways to Protect Environment	Ask + Answer Questions	Cause + Effect
Fully developed	Fully developed	Not Evident

Thoughts: - The lesson developed SEPs and DCIs
- Teacher did not cover the cause + Effect concept

Lesson Plan:
- Students identify Resources
- Students explain how the use of resources affect the environment
- Tell how to protect the environment.

Thoughts: The focus was learning the 3Rs. classify 3Rs and categorize 3Rs.
- Students did not hit the explanation part which covers Cause + Effect

Btech

Note. This snippet of my reflexive journal shows the documentation of thoughts after a classroom observation.

Summary

This chapter described the setting of the study, the participants' demographics, data collection, and data analysis process. The data analysis underwent various coding rounds, and four themes emerged from the participants' responses to the interview questions, lesson plans, and classroom observations. Theme 1 explored participants' positive perceptions of implementing the standards. Overall, teachers felt comfortable teaching NGSS and only cited a few challenges in teaching them. Theme 2 explained how the standards positively affected teaching science. In general, the participants cited that the standards created more student-centered classrooms and pushed for new ways of teaching science. Theme 3 described participants' pedagogical knowledge and connection to choosing practices and resources to cover the standards. Most of the participants were fine with the new standards' topics and felt they could choose practices and resources that cover NGSS.

Generally, participants referred to a published program to guide the classroom instructions. They did significant amounts of research and utilized a variety of websites to get additional resources. Most participants cited a preference for choosing practices according to the domains of science. Few explained that the inquiry approaches work best with any topic of teaching. Theme 4 explained the result of data triangulation to show that participants have disconnected perceptions of what they are teaching with what the standards require. Although most teachers implemented hands-on, student-centered practices, these did not necessarily develop the three dimensions of the standards. The last section of the chapter described the strategies that I used to ensure data trustworthiness. The following chapter includes interpretations of the findings in the context of Shulman's (1986) PCK framework, limitations of the study, recommendations for future research, and implications for social change in teaching NGSS. The chapter concludes with a conclusion on why this study proved necessary.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this exploratory qualitative case study was to better understand how elementary teachers use PCK and curricular knowledge to implement instructional practices that integrate the three dimensions of NGSS when teaching science at American private schools in the UAE. Ravitch and Carl (2016) explained that qualitative research is about viewing and understanding people who have expertise within the context that is being studied. Understanding teachers' attitudes and perceptions related to the implementation of NGSS served as a rationale for choosing the qualitative method for the study.

The key findings of this study provide a deeper understanding of how teachers use instructional practices to integrate the three dimensions of NGSS by comprehending the experiences and perceptions of teachers as they implement NGSS within Shulman's (1986) PCK framework. Data results answered the following RQs:

RQ1: How do elementary teachers implement instructional practices that integrate the three dimensions when teaching NGSS at American private schools in the UAE?

RQ2: How do elementary teachers integrate their PCK and curricular knowledge when implementing instructional practices that teach the three-dimensional content of NGSS?

I aimed to recruit 10 participants with at least 3 years of experience in teaching NGSS. I used a shared set of questions derived from the RQs and Shulman's (1986) PCK framework. I also interviewed teachers who taught across different grade levels to have a broader understanding of teachers' experience with implementing NGSS. Triangulating interview data with classroom observations and lesson plans helped draw a clearer image of teaching three-dimensional standards. The findings of this study reveal that teachers have a positive perception regarding their implementation of the standards. There have been a few changes in terms of content and a few cited challenges. Overall, there were fundamental constructive changes in the way participants taught science at the elementary level. There was an increase in student-centered activities and inquiry opportunities. Students were now required to make sense of what they are learning. Participants used cooperative learning strategies and reflections effectively in their teaching. However, there was an apparent mismatch between participating teachers' perceptions of implementing the three dimensions and the actual coverage of the standards. In the following section, I will interpret the critical findings of my study and provide further interpretations in light of the research.

Interpretation of the Findings

I examined the findings of the study in relation to the literature review outlined in Chapter 2. To further understand the interview findings, I reviewed additional literature. All findings are explained in relation to Shulman's (1986) PCK framework. Four themes emerged from the analysis of data to answer the RQ1, which concerned how elementary teachers implement instructional practices that integrate the three dimensions when teaching NGSS at American private schools in the UAE. The themes that emerged are related to teachers' positive perceptions of the standards and the positive changes in their teaching. These two themes describe the instructional practices that participants used to teach the standards. Two additional themes emerged to answer RQ2, which concerned how elementary teachers integrate their PCK and curricular knowledge when implementing instructional practices that teach the three-dimensional content of NGSS. The third theme explained how participants integrate their PCK with curricular knowledge to choose practices that they believe are a good fit to teach NGSS. The fourth and last theme explored the disconnection between teachers' perceptions of implementing the standards and the actual implementation of NGSS. It showed that teachers are not covering the three dimensions of the standards.

Theme 1: Positive Perceptions of Implementing the Next Generation Science Standards

The first theme addresses participants’ perceptions of the NGSS standards, their positive views of NGS, and the challenges of teaching them. Participants had positive beliefs that are aligned with the requirements of NGSS. They viewed NGSS as a framework that specifies what students need to know. Few participants cited the three-dimensional nature of NGSS, but all of them considered that the standards are an inquiry-based approach to teaching science. Having these positive beliefs and perceptions on the NGSS is consistent with published literature that shows teachers have aligned beliefs with the reforms of NGSS (Hayes et al., 2019; Smith, 2020). Consistent with other studies, participants’ extensive experience in teaching science and possession of content knowledge played a role in their positive perception of the implementation process (see Wong et al., 2023). All participants had more than 3 years of experience in teaching the standards. A design-based research study (N = 80) by Wong et al. (2023) confirmed that teachers' science content knowledge and STEAM teaching perceptions were directly associated with their level of self-efficacy.

When asked about the challenges of teaching NGSS, two participants cited the lack of resources as a primary challenge. The challenge caused by the lack of resources is consistent with studies showing that elementary science classrooms are often undersupplied with resources (Barrett-Zahn, 2019; National Academies of Science, Engineering, and Medicine, 2022; Smith & Nadelson, 2017). Two other participants cited a lack of teaching time as a challenge for teaching NGSS. National Academies of Science, Engineering, and Medicine (2022) report stated that science teachers need more time to develop three-dimensional standards. Lack of time was also echoed in a multilevel linear modeling study on eighth-grade teachers in 6,850 U.S. public schools ($N = 11{,}520$) by Kolbe et al. (2020), which highlighted that teachers are more likely to integrate inquiry and practices into their content if they have more time to teach science.

Theme 2: Positive Changes in Teaching

The second theme covers the positive changes in teaching science, which include the use of new inquiry-based approaches to teaching and the support of student-centered strategies in the classroom. The interpretation shows research related to the use of new positive approaches to teaching science. The results presented in Chapter 4 show a positive increase in teacher inquiry approaches to teaching science. Participants cited a positive movement towards using student centered practices in the classroom. Findings also supported that participants are choosing and implementing inquiry-led lessons with more opportunities for hands-on and explorations. They are also connecting science to other disciplines through cross-curricular connections. The literature confirms that NGSS requires significant shifts in teaching science. NGSS has integrated STEM within teaching science (Hoeg & Bencze, 2017; Lesseig et al., 2016; Rose et al., 2017; Whitworth & Wheeler, 2017; Wright et al., 2019). A primary pedagogical approach that promotes STEM and is embedded within the practices of NGSS is inquiry learning (Spires et al., 2022).

Inquiry learning allows teachers to immerse students in real-world situations where they can use their knowledge and skills to develop projects or experiments (Kolbe et al., 2020). All participants cited inquiry-oriented learning as a prominent change in their classrooms. NGSS challenges students to work like scientists to solve authentic, real-world problems by integrating inquiry-based teaching with authentic practices (Hang et al., 2020). Students are learning to make sense of science rather than learning about it, which conforms with the mixed method study ($N = 109$) on elementary science teachers by Seung et al. (2023) stated that NGSS requires teachers to create learning experiences where students ask fundamental questions about science and try to pursue answers.

The increase in cross-curricular connection two participants cited is also found in the literature. The NGSS standards are explicitly connected to CCSS standards for mathematics and ELA (NGSS Lead States, 2013a). Cross-curricular connections allow teachers to integrate different subjects (Lee, 2017). Moreover, both ELA and CCSS standards for mathematics and ELA focus on the same skills, making the linkage between subjects more accessible (Lee, 2017; Novak et al., 2016).

The results also show that participants view NGSS and the practices as the driving force to change their classroom setting into a student-centered setting where students act like scientists and engage in scientific practices. Smith (2020) stated that elementary NGSS science classes have shown improvement in engaging students in classroom discussions, engaging them in small group work, doing less reading and more hands-on activities, and using PBL as an instructional approach.

Theme 3: Integration of Pedagogical Content Knowledge With Curricular Knowledge

The focus of the third theme is on how teachers use their PCK and curricular knowledge when choosing teaching practices. The third theme also covers how teachers prepare resources and plans that teach new concepts in light of literature findings. The participants had positive views on the level of their PCK, and this translated into using instructional practices they felt were most suitable to cover areas of science that they know or are new to them. The connection between teachers' perceptions and inquiry practices is confirmed in the study conducted within the context of the Interdisciplinary Science and Engineering Partnership ($N = 509$) by Yang et al. (2018), which positively correlates teachers' understanding of the nature of science to their attitudes and support for inquiry. Suh and Park (2017) cite a multiple case study conducted with three experienced grade five teachers showing a connection between teachers' epistemological orientation, knowledge, and the ability to implement innovative teaching practices. Teachers are more likely to implement innovative teaching practices if they have pedagogical knowledge and aligned beliefs with the reforms. Accordingly, six participants cited that the standards did not introduce new topics to teach. Four of the participants cited one new content that was new to them. Nevertheless, they did not view this as a struggle with teaching the new content.

Participants chose their practices based on merging between their PCK and curricular knowledge. They used their expertise to choose the practices that fit their teaching domain. As stated in Chapter 4, participants did not choose the same practices to teach the different domains of science. For example, a participant cited that hands-on cannot be used with life science, while another said that weather can be only taught with hands-on lab activities. Krepft et al. (2018) remarked that teachers need to have knowledge of the details of the topic and the pedagogical content of the effective methods to plan and teach a lesson. Some participants also cited that they chose practices based on students' levels, presented in an explanatory sequential mixed methods ($N = 39$) study showing that secondary teachers practice inquiry depending on students' levels (Kaya et al., 2020). Participants' choice of practices is consistent with published literature. The mixed method study on elementary preservice science teachers ($N = 109$) by Seung et al. (2023) showed that teachers often chose asking questions, planning and carrying out investigations, analyzing and interpreting data, and modeling as the leading practices. Accordingly, participants cited modeling, investigations, and explorations as their primary choice of practices. Their choice of practices was also evident in their lesson planning and classroom observations.

Chapter 4 results showed that participants deploy research and use a variety of websites to acquire the required topic-related knowledge. Findings also show that participants rely on commercially published programs to teach the NGSS standards as their central resource, which conforms with studies that showed teachers use commercially published material and search the internet to find lesson plans to teach NGSS (Boesdorfer et al., 2020; Shelton, 2021).

Theme 4: Disconnection Between Perceptions of Implementing the Next Generation Science Standards and the Actual Implementation

The interpretation of the last theme shows a misalignment and disconnection between what teachers perceive as NGSS-aligned instructions and the actual requirements of NGSS. While teachers have increased inquiry and student-centered activities, the implementation of three-dimensional teaching and learning was still missing in the majority of the lessons observed. Examining lesson plans and conducting lesson observations showed that teachers' perception of their self-efficacy does not translate into a proper implementation of the three dimensions of the standards. Participants shared in their interviews that they chose student-centered activities and instructional practices covering the standards. This was not evident in the classroom observations and lesson plans as they showed a misalignment between the content, practices, and the requirements of the standards. Some participants were setting up centers with activities that did not match the content of the standard. Other participants were using hands-on inquiries that contradict the requirements of NGSS. In all the observations, teachers did not deliver three-dimensional instructions. The mismatch between perception and implementation is cited in multiple literature findings. A qualitative study by Kawasaki and Sandoval (2020) on middle and high school science teachers ($N = 7$) showed that teachers revised the lessons to make them more student-centered. However, the strategies were misaligned with the NGSS teaching. The mixed method exploratory study on teachers in Chicago Public Schools ($N = 1{,}029$) by Allensworth et al. (2022) demonstrated that although teachers are aligning their practices to fit NGSS, they find it challenging to engage students in the high conceptual processes of the NGSS. A report by Smith (2020) confirmed that teachers may have aligned beliefs with NGSS yet fail to deliver NGSS instructions. Each of the literature findings was true with the participants. While they have delivered high-quality, student-centered, engaging lessons and articulated support for the NGSS standards, they struggled to choose instructional practices that align with or cover the three dimensions of NGSS.

Triangulating observations, lesson plans, and interview findings demonstrated that participants failed to teach the three-dimensional standards. Participants chose practices that did not align with the requirements of the standards, relied heavily on content, or did not cover the crosscutting concepts. Failure to deliver three-dimensional instructions is consistent with literature findings. Several studies have illustrated that teachers' aligned beliefs with the reforms do not translate into choosing the proper practices. A qualitative analysis study of teachers' pedagogical reflections across different grade levels ($N = 165$) by Canstronova and Chernobilsky (2020) showed that teachers focused on SEPs in their NGSS reforms, with 51% of these teachers noticing a misalignment in their practices. A similar qualitative study on middle school and high school science teachers ($N = 7$) by Kawasaki and Sandoval (2020) showed that the strategies used by teachers in the study could be useful to create student-centered classrooms. Yet, teachers underestimated how their usage of the practices needed to be different to align with NGSS. Teachers fail to see how the standards are inseparable and how they integrate to create three-dimensional learning (Froschauer, 2017; Jin & Mikeska, 2017). They tend to teach only a few of the practices (Hayes et al., 2016; Reiser et al., 2017) and are confused about how to teach the crosscutting concepts (Fick et al., 2022; Goggins et al., 2019; Kang et al., 2018; Osborne at al., 2018; Talanquer, 2019). Thus, teachers fail to deliver three-dimensional teaching.

Lesson observations showed that when the participants used lab experiments, they followed guided step-by-step scientific method recipes that did not assist in making sense of a natural phenomenon. For example, structured lab experiments contradict the requirements of NGSS, which calls for a move away from the cookbook approaches to teaching science to more sense-making (Dickinson et al., 2020). The same concerns are consistent with literature stating that most teachers have a linear view of the scientific method that does not match the requirements of NGSS (Merritt et al., 2018), so they fail to provide authentic NGSS labs and activities (Colson & Colson, 2016). Smith (2020) explained that 75% of science teachers still define new vocabulary at the beginning of instruction, more than half use laboratory activities to reinforce content taught, and one in three teachers explicitly explain ideas to students. These practices were observed amongst the participants' instructions.

Most of the participants use commercially published resources to teach NGSS. Follow-up interview results suggest that published resources contributed to the misalignment in covering the NGSS standards. Literature confirms a lack in the amount and quality of commercially published resources to support the proper implementation of the NGSS (Haas et al., 2021; Lowell et al., 2021; Shelton, 2021; Smith, 2020). The lack of high-quality curriculum resources makes delivering three-dimensional instructions a more challenging.

Limitations of the Study

As discussed in Chapter 1, the study is limited to the confines of the examined population, specifically elementary science teachers in the UAE with at least 3 years of teaching NGSS and their environment, which is American private schools with bilingual students from various demographical backgrounds. With the study being confined to a specific geographical region, transferability to other regions in other geographic locations with different demographic populations needs to be evaluated. I provided thick demographic descriptions to enhance transferability (Ravitch & Carl, 2016). Interested researchers must consider how much the findings can apply to their context.

Qualitative research has no set rule for the number of participants in the study, as the goal is not to generalize but to "rigorously, ethically and thoroughly answer your RQs to achieve a complex and multi-perspectival understanding" (Ravitch & Carl, 2016, p. 137). The sample size for this research is suitable for an exploratory qualitative study. The aim was to have a deeper understanding of the implementation of NGSS by interviewing 10 elementary science teachers and observing the classrooms of eight of these teachers. Concept saturation was achieved with the chosen sample size. The results provided a valuable understanding of how teachers implement the NGSS; however, they might not be suitable for generalizations to all teachers implementing the NGSS.

Due to logistics and restraints, I was able to observe only eight out of the 10 teachers who were interviewed. Moreover, I only received six lesson plans to triangulate. Obtaining less data created another limitation as I could not triangulate all interview findings with the classroom observations and lesson plans. While there was a consistent trend in all the observed lessons and documented lesson plans, it is hard to assume how the missing data would add to or alter the findings.

Another limitation in the data collection was using interviews as the primary method to understand participants' implementation of the standards. This limitation was covered using observation of classrooms and examining lesson plans. Data findings showed a gap between teachers' beliefs about implementing NGSS and their classroom practices. Data findings from observations could be triangulated with lesson plans, but they portrayed a better understanding and a misalignment from the teachers' responses to interview questions.

Another limitation was researcher bias. Researcher bias is an internal threat to qualitative studies (Burkholder et al., 2016). I followed protocols, used the same set of questions and lesson screener, and adhered to my data collection plan to avoid bias. I carefully conducted self-checks and self-evaluations and documented my thoughts in a reflexive journal to increase confirmability (Burkholder et al., 2016).

Recommendations

Research on the implementation of NGSS in the UAE is scarce. This study uncovers teachers' perceptions and implementation of the three-dimensional standards. The findings showed that teachers' preparedness to teach the three dimensions of the

NGSS is still in question, as teachers are not using instructional practices that cover the three dimensions of the NGSS. Teachers have positive perception of the reform and have successfully implemented student-centered strategies, yet they need to focus more on the standards' implementation. The first recommendation covers training and professional development. Teachers need the proper training to help them unpack the standards and engage in authentic discussions around the standards to create three-dimensional experience for students. Kawasaki and Sandoval (2020) explained that fixing the misalignment between teachers' own goals and the goals of NGSS reforms can be achieved with professional development. Another study by Seung et al. (2023) illustrated that teachers who underwent an elementary science teaching methods course changed their epistemic understanding of the practices and could integrate practices with crosscutting concepts more effectively in the classroom.

Another recommendation is using high-quality curriculum material to assist teachers in implementing the standards. Smith (2020) cited is a lack of high-quality NGSS material available for teachers. Lowell et al. (2021) analyzed existing commercial NGSS curricula to evaluate alignment. The study concluded that the published curriculum is branded as NGSS aligned, yet it oversimplifies the complex requirements of NGSS and is misaligned with NGSS requirements. A similar study by Lowell and McGowan (2022) stated that 8 years into the publication of NGSS, most of the available publications still do not align with NGSS requirements and teachers are usually left to figure out what works for students. The need for aligned resources calls for more supervision by Achieve or publishers around labeling commercial material as NGSS-aligned.

Implications

This study promotes positive change by providing better information on how teachers implement the three dimensions of NGSS. The study has various implications in different areas. This study's practical implications include deciding what training and professional development courses are needed to better assist teachers in delivering three-dimensional instructions. On the other hand, policy implications include constructing better policies on the quality of material used. Theoretical and empirical implications suggest areas of future research.

The recommendations noted that teachers need more support in unpacking and understanding the three dimensions of the standards and how they work together to create a three-dimensional learning experience. Practical implications for this study include the need for school leaders and principals to allocate the proper training and professional development to assist their teachers in covering the standards. It also includes that training programs and trainers must revise their training to make it more practical. Teachers who have aligned beliefs with the reforms of NGSS but do not translate them into classroom instructions would benefit from programs that show them how to infuse PCK with practices to implement the standards better (Hayes et al., 2019). Extensive and targeted professional development on implementing NGSS can help teachers change their mindset on how science instructions should look like in a classroom (Barrett-Zahn, 2019). Practice-focused professional development schemes need to include practice scenarios where teachers experience three-dimensional learning by examining and applying how they can support students in building their knowledge (Reiser et al., 2017). By properly connecting the three dimensions of NGSS, teachers can equip the students with reasoning skills that can assist them in developing explanations and designing solutions as required by NGSS (Kang et al., 2018).

Teachers might still feel that they cannot fully comprehend all the requirements of NGSS with professional development (Smith, 2020; Tuttle et al., 2016). Therefore, high quality NGSS-aligned material is a necessity (Lowell et al., 2021). Research provided little clarity on how to integrate the three dimensions of NGSS when developing curriculum, pedagogy, or assessment, which creates a misalignment between the standards and curriculum material (Fulmer et al., 2018). Policy implications for this study include calling on policymakers to make better decisions on how to create or evaluate curriculum materials that are better aligned with NGSS to help support teachers in their implementation efforts. While Achieve has created a rubric to help teachers evaluate curriculum alignment with NGSS, they might consider endorsing or creating curriculum material that they have tested to better align with the requirements of NGSS. This would help teachers as they are teaching the three-dimensional standards.

The study helps fill a gap in the literature on how teachers use their pedagogical and content knowledge in choosing instructional practices that can deliver the three dimensions of NGSS. The empirical implications of this study include further research to help understand the reasons for the misalignment between perception and implementation and the effect of training or professional development courses on bridging this gap.

Another theoretical implication of this study would be a revision of the elements of Shulman's (1986) PCK framework considering the vision proposed by the NGSS. The proper implementation, training, and instructional material will assist in delivering the proper three-dimensional instructions required by NGSS. Proper NGSS coverage would help increase student achievement on international benchmark assessments to achieve the requirements of the UAE National Agenda.

Conclusion

There was a need to better understand how teachers' understanding of the three-dimensional standards of NGSS enables them to choose practices for effective delivery (Fulmer et al., 2018; Hanuscin & Zangori, 2016). The purpose of this exploratory qualitative study is to help understand how teachers integrate their PCK and curricular knowledge when implementing strategies to cover NGSS standards. Shulman's (1986) PCK framework was used in this study to frame the RQs around teachers' use of instructional practices that deliver the three dimensions of the NGSS and the role of PCK and curricular knowledge in choosing these practices.

This qualitative study found that teachers have beliefs aligned with the NGSS reforms and use student-centered classroom practices. Teachers relied on their teaching experience, pedagogical knowledge, and content knowledge in choosing inquiry practices that fit the domains of science. Teachers were keen on using hands-on, inquiry-driven practices that fit their vision of student-centered classrooms. Teachers used commercially published curricula along with additional websites and visuals to simplify and deliver engaging activities. When triangulating teachers' interview findings with the lesson plans and classroom observations, it was noticed that teachers were not delivering the three-dimensional requirements of the NGSS. Teachers' choice of activities and practices were often misaligned with those of NGSS. Their lessons were content-driven, and the teaching of crosscutting concepts was not evident in the classroom observations.

On a closer look, teachers were all using commercially published curricula that scripted the lessons, instructions, and standards to be taught. Upon follow-up interviews, it was noticed that teachers' reliance on published material that did not fully align with the vision of NGSS resulted in a mismatch with the requirements of the standards. It was also concluded that teachers need to have the opportunity to work firsthand on unpacking the standards and understanding the innovations of NGSS to deliver instructional practices that are more aligned with the three-dimensional vision of NGSS.

Equipping the teachers with opportunities to unpack and implement the standards firsthand through professional development scenarios linked with real-life practices from real classroom observations will help them align their beliefs and instructional practices with the requirements of NGSS. All science teachers need to have the opportunity to reflect on what they are doing about the requirements of NGSS. Having trusted, aligned resources endorsed or created by Achieve or any other reliable entity will help them deliver instructional practices that can cover the three dimensions of NGSS. Teaching NGSS standards will help create classroom environments that will shift the focus from covering content to allowing students’ application of science and engineering practices to real-world situations and design solutions for real-world problems (National Academies of Sciences, Engineering, and Medicine, 2018).

References

Andersson, J., Sitzman, D., Arneson, A., & Gandhi, E. (2021). With new science standards, coaching is key. *Learning Professional*, *42*(1), 44–48. https://conference.learningforward.org/wp-content/uploads/2021/02/with-new-science-standards-coaching-is-key.pdf

Allensworth, E., Cashdollar, S., & Cassata, A. (2022). Supporting change in instructional practices to meet the Common Core Mathematics and Next Generation Science Standards: How are different supports related to instructional change? *AERA Open*, *8*(1), 1–15. https://doi.org/10.1177/233285842210880

Al Maktoum, M. B. R. (2014). *United Arab Emirates Vision 2021*.

Al Naqbi, A. K. (2019). Inquiry-based instruction of eight Emirati elementary preservice science teachers: A phenomenographic study. *International Interdisciplinary Journal of Education*, *8*(3), 142–154. https://doi.org/10.36752/1764-008-003-010

Aydarova, E. (2017). Discursive contestations and pluriversal futures: A decolonial analysis of educational policies in the United Arab Emirates. *Education Policy Analysis Archives*, *25*(111/112), 1–26. https://doi.org/10.14507/epaa.25.3063

Babbie, E. (2017). *The basics of social research* (7th ed). Cengage Learning.

Barrett-Zahn, E. (2019). Shifting from kits to NGSS strategies. *Science and Children,* *56*(8), 6–9.

Bernhard, T. (2023). Science teacher educators' visions and evaluations of expertise in NGSS-aligned instruction across institutions. *Journal of Science Teacher Education*, *34*(4), 369–390. https://doi.org/10.1080/1046560X.2022.2105706

Bielik, T., Finnie, K., Peek-Brown, D., Klager, C., Touitou, I., Schneider, B., & Krajcik, J. (2022). High school teachers' perspectives on shifting towards teaching NGSS-aligned project-based learning curricular units. *Journal of Science Teacher Education*, *33*(4), 413–434. https://doi.org/10.1080/1046560X.2021.1961973

Boesdorfer, S. B., Arias, A. M., Mull, B., & Lieberum, K. (2020). Characterization of curriculum materials to support NGSS-aligned engineering instruction in chemistry teaching. *School Science and Mathematics*, *120*(7), 425–440. https://doi.org/10.1111/ssm.12431

Bouchard, J. (2021). *Pedagogical content knowledge*. In *Salem Press Encyclopedia*. Great Neck Publishing.

Boyd, J. (2022). *A nation at risk*. In *Salem Press Encyclopedia*. Great Neck Publishing.

Braun, H. I., & Singer, J. D. (2019). Assessment for monitoring of education systems: International comparisons. *Annals of the American Academy of Political & Social Science*, *683*, 75–92. https://doi.org/10.1177/0002716219843804

Buckner, E., Chedda, S., & Kindreich, J. (2016, June). *Teacher professional development in the UAE: What do teachers actually want?* (Policy paper No. 16). Sheikh Saud Bin Saqr Al Qasimi Foundation for Policy Research. https://cdn2.hubspot.net/hubfs/5081768/Alqasimifoundation%20-%202018/Research%20Publications%201%20/Policy%20Paper%20No.%2016.pdf?__hstc=78953035.928d375fa779cab42d866e1fabea7f92.1703121288656.1703121288656.1703121288656.1&__hssc=78953035.1.1703121288657&__hsfp=2808466684&hsCtaTracking=004c1cb3-fa16-4ad9-a094-

cd143ca59c50%7Cec235772-84c9-4d8f-a345-10295b4f1b3d

Burkholder, G. J., Cox, K. A., & Crawford, L. M. (2016). *The scholar-practitioner's guide to research design*. Laureate Publishing.

Butin, D. W. (2010). *The education dissertation: A guide for practitioner scholars*. Corwin.

Bybee, R. W. (2006). *Teaching science in the 21st century*. National Science Teachers Association.

Castillo-Montoya, M. (2016). Preparing for interview research: The interview protocol refinement framework. *The Qualitative Report*, *21*(5), 811–831. https://nsuworks.nova.edu/tqr/vol21/iss5/2

Castronova, M., & Chernobilsky, E., (2020) Teachers' pedagogical reflections on the Next Generation Science Standards. *Journal of Science Teacher Education*, *31*(4), 401–413. https://doi.org/10.1080/1046560X.2019.1710387

Chaya, H. (2023). Investigating teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. *Journal of Education and Learning*, *12*(2), 60–78.

Chorev, N., & Ball, A. C. (2022). The knowledge-based economy and the global south. *Annual Review of Sociology*, *48*, 171–191. https://doi.org/10.1146/annurev-soc-080321-071214

Christian K.B., Kelly, A. M., & Bugallo. M. F. (2021). NGSS-based teacher professional development to implement engineering practices in STEM instruction. *International Journal of STEM Education*, *8*, Article 21.

https://doi.org/10.1186/s40594-021-00284-1

Colson, M., & Colson, R. (2016). Planning NGSS-based instruction: Where do you start? *Science Scope, 39*(6), 16–18. https://doi.org/10.2505/4/ss16_039_06_16

Dailey, D. (2017). Using engineering design challenges to engage elementary students with gifts and talents across multiple content areas. *Gifted Child Today, 40*(3), 137–143. https://doi.org/10.1177/1076217517707236

Danielson, K., & Matson, C. (2018). Designing an NGSS learning pathway: How informal institutions can help teachers implement the NGSS. *Science & Children, 55*(7), 69–74. https://doi.org/10.2505/4/sc18_055_07_69

Diamond, B. S., Maerten-Rivera, J., Rohrer, R. E., & Lee, O. (2014). Effectiveness of a curricular and professional development intervention at improving elementary teachers' science content knowledge and student achievement outcomes: Year 1 results. *Journal of Research in Science Teaching, 51*(5), 635–658. https://doi.org/10.1002/tea.21148

Dickinson, E. R., Thacker, A. A., & Michaels, H. R. (2020). NGSS alignment: Where have we been and where are we going? *Educational Measurement: Issues and Practice, 39*(2), 31–34. https://doi.org/10.1111/emip.12331

Dima, A. M., Begu, L., Vasilescu, M. D., & Maassen, M. A. (2018). The relationship between the knowledge economy and the global competitiveness in the European Union. *Sustainability, 10*(6),1–15. https://doi.org/10.3390/su10061706

Doering, A., Veletsianos, G., Scharber, C., & Miller, C. (2009). Using the technological, pedagogical and content knowledge framework to design online learning environments and professional development. *Journal of Educational Computing Research, 41*(3), 319–346. https://doi.org/10.2190/EC.41.3.d

Dove, A. (2002). It takes a village to raise an idiot: Fixing the US science education. *Journal of Clinical Investigation, 110*(8), 1057.

El Afi, A. D. (2019). The impact of professional development training on teachers' performance in Abu Dhabi cycle two and three school. *Teacher Development, 23*(3), 366–386. https://doi.org/10.1080/13664530.2019.1589562

El-Deghaidy, H., Mansour, N., Alzaghibi, M., & Alhammad, K. (2017). Context of STEM integration in schools: Views from in-service science teachers. *EURASIA Journal of Mathematics, Science & Technology Education, 13*(6), 2459–2484. https://doi.org/10.12973/eurasia.2017.01235a

Eltanahy, M., & David, S. A. (2018). A study investigating the factors influencing predominant teaching strategies used in American curriculum schools in the United Arab Emirates. *International Journal of Teaching and Case Studies, 9*(3), 275-290. https://doi.org/10.1504/IJTCS.2018.10014660

Fick, S. J. (2018). What does three-dimensional teaching and learning look like? Examining the potential for crosscutting concepts to support the development of science knowledge. *Science Education, 102*(1), 5–35. https://doi.org/10.1002/sce.21313

Fick, S. J., Chiu, J. L., & McElhaney, K. W. (2022). An examination of elementary classroom dialogue: Implicit and explicit use of the NGSS crosscutting concepts in an integrated STEM unit. *Journal of Science Teacher Education, 33*(4), 435–

457. https://doi.org/10.1080/1046560X.2021.1961974

Froschauer, L. (2017, December). Developing coherent lessons with the NGSS and 5E. *Science and Children*, *4*(0036-8148), 5. https://www.nsta.org/resources/editors-note-developing-coherent-lessons-ngss-and-5e

Fulmer, G. W., Tanas, J., & Weiss, K. A. (2018). The challenges of alignment for the Next Generation Science Standards. *Journal of Research in Science Teaching, 55*(7), 1076–1100. https://doi.org/10.1002/tea.21481

Gaad, E., Arif, M., & Scott, F. (2006). Systems analysis of the UAE education system. *International Journal of Educational Management, 20*(4), 291–303. https://doi.org/10.1108/09513540610665405

Gale, J., Koval, J., Ryan, M., Usselman, M., & Wind, S. (2019). Implementing NGSS engineering disciplinary core ideas in middle school science classrooms: Results from the field. *Journal of Pre-College Engineering Education Research, 9*(1), 11–29. https://doi.org/10.7771/2157-9288.1185

Goggins, M., Haas, A., Grapin, S., Llosa, L., & Lee, O. (2019). Integrating crosscutting concepts into science instruction: This vital dimension of the NGSS can build on students' everyday experiences in their homes and communities. *Science & Children, 57*(2), 56–61.

Government of Dubai.(2022). Dubai private schools sector records highest ever enrolment. https://mediaoffice.ae/en/news/2022/April/14-04/Dubai-private-schools-sector-recordshighest-ever-enrolment

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

Haas, A., Januszyk, R., Grapin, S.E., Goggins, M., Llosa, L., & Lee, O. (2021). Developing instructional materials aligned to the Next Generation Science Standards for all students, including English Learners. *Journal of Science Teacher Education, 32*(7), 735-756. https://doi.org/10.1080/1046560X.2020.1827190

Hammack, R., & Ivey, T. (2017). Examining elementary teachers' engineering self-efficacy and engineering teacher efficacy. *School Science & Mathematics, 117*(1/2), 52–62. https://doi.org/10.1111/ssm.12205

Han, J., & Kelley, T. R. (2022). STEM Integration through shared practices: Examining secondary science and engineering technology students' concurrent think-aloud protocols. *Journal of Engineering Design*, *33*(5), 343–365. https://doi.org/10.1080/09544828.2022.2042498

Hang, N.T., & Srisawasdi, N. (2021). Perception of the next generation science standard instructional practices among Vietnamese pre-service and in-service teachers. *Journal of Technology and Science Education, 11*(2), 440-456. https://doi.org/10.3926/jotse.1154

Hanuscin, D. L., & Zangori, L. (2016). Developing practical knowledge of the next generation science standards in elementary science teacher education. *Journal of Science Teacher Education, 27*(8), 799–818. https://doi.org/10.1007/s10972-016-9489-9

Harlow, D. (2014). An investigation of how a physics professional development course influenced the teaching practices of five elementary school teachers. *Journal of Science Teacher Education, 25*(1), 119–139. https://doi.org/10.1007/s10972-013-9346-z

Harris, K., Sithole, A., & Kibirige, J. (2017). A needs assessment for the adoption of Next Generation Science Standards (NGSS) in K-12 education in the United States. *Journal and Training Studies, 5*(9), 54–62. https://doi.org/10.11114/jets.v5i9.2576

Hayden, H. E., & Eades-Baird, M. (2020). Disciplinary literacy and the 4Es: rigorous and substantive responses to interdisciplinary standards. *Literacy Research: Theory, Method, and Practice, 69*(1), 339–357. https://doi.org/10.1177/2381336920937258

Hayes, K., Lee, C., DiStefano, R., O'Connor, D., & Seitz, J. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *Journal of Science Teacher Education, 27*(2), 137–164. https://doi.org/10.1007/s10972-016-9448-5

Hayes, K. N., Wheaton, M., & Tucker, D. (2019). Understanding teacher instructional change: the case of integrating NGSS and stewardship in professional development. *Environmental Education Research, 25*(1), 115–134. https://doi.org/10.1080/13504622.2017.1396289

Hoeg, D. G., & Bencze, J. L. (2017). Values underpinning STEM education in the USA: An analysis of the Next Generation Science Standards. *Science Education, 101*(2), 278–301. https://doi.org/10.1002/sce.21260

Holthuis, N., Deutscher, R., Schultz, S. E., & Jamshidi, A. (2018). The new NGSS classroom: A curriculum framework for project-based science learning. *American Educator, 42*(2), 23–27.

Houseal, A. K. (2016). A visual representation of three-dimensional learning: A model for understanding the power of the framework and the NGSS. *Electronic Journal of Science Education, 20*(9), 1–7.

Huff, K. L. (2016). Addressing three common myths about the Next Generation Science Standards. *The Science Teacher*, (1), 55. https://doi.org/10.2505/4/ss16_039_05_16

Hufnagel, E., Kelly, G. J., & Henderson, J. A. (2018). How the environment is positioned in the Next Generation Science Standards: A critical discourse analysis. *Environmental Education Research*, *24*(5), 731–753. https://doi.org/10.1080/13504622.2017.1334876

Ibrahim, A. & Al-Taneiji, S. (2019). Teacher satisfaction in Abu Dhabi public schools: What the numbers did not say. *Issues in Educational Research, 29*(1), 106–122. http://www.iier.org.au/iier29/ibrahim.pdf

Isabelle, A. D. (2017). STEM is elementary: Challenges faced by elementary teachers in the era of the Next Generation Science Standards. *Educational Forum, 81*(1), 83–91. https://doi.org/10.1080/00131725.2016.1242678

Jackson, L. (2015). Challenges to the global concept of student-centered learning with special reference to the United Arab Emirates: 'Never fail a Nahyan.' *Educational Philosophy & Theory, 47*(8), 760–773. https://doi.org/10.1080/00131857.2014.901161

Jin, H., & Mikeska, J. N. (2017). Teaching NGSS-aligned lessons in science classrooms. *Science Scope, 41*(3), 59–66. https://doi.org/10.2505/4/ss17_041_03_59

John, V. K., & Varghese, M. M. (2018). STEM: A study in the schools of Dubai, UAE. *Annual International Conference on Education & E-Learning*, 36–42. https://doi.org/10.5176/2251-1814_EeL18.121

Kang, E. J. S., Donovan, C., & McCarthy, M. J. (2018). Exploring elementary teachers' pedagogical content knowledge and confidence in implementing the NGSS science and engineering practices. *Journal of Science Teacher Education, 29*(1), 9–29. https://doi.org/10.1080/1046560X.2017.1415616

Kang, E. J. S., McCarthy, M. J., & Donovan, C. (2019). Elementary teachers' enactment of the NGSS science and engineering practices. *Journal of Science Teacher Education*, 1–27. https://doi.org/10.1080/1046560X.2019.1630794

Kawasaki, J., & Sandoval, W. A. (2020). Examining teachers' classroom strategies to understand their goals for student learning around the science practices in the Next Generation Science Standards. Journal of Science Teacher Education, 31(4), 384–400. https://doi.org/10.1080/1046560X.2019.1709726

Kaya, E., Newley, A., Yesilyurt, E., & Deniz, H. (2019). Research and teaching: Improving preservice elementary teachers' engineering teaching efficacy beliefs with 3D design and printing. *Journal of College Science Teaching, 48*(5), 76–83.

Knowledge and Human Development Authority. (2015, August 24). United Arab

Emirates: School inspection framework 2015-2016. https://web.khda.gov.ae/en/Resources/Publications/School-Inspection/UAE-School-Inspection-Framework-2015-16

Knowledge and Human Development Authority. (2016, June 30). Dubai Inspection Bureau: School inspection supplement 2016-2017. https://www.khda.gov.ae/Areas/Administration/Content/FileUploads/Publication/Documents/English/20160907105519_KHDAInspectionSupplementEnglish.pdf

Knowledge and Human Development Authority. (2017). Dubai TIMSS 2015: Journey towards the United Arab Emirates national agenda. https://khda.gov.ae/Areas/Administration/Content/FileUploads/Publication/Documents/English/20170718150710_DUBAI_TIMSS_EN.pdf

Knowledge and Human Development Authority. (2023). Growth and quality in Dubai private schools 2023/24. https://web.khda.gov.ae/en/Resources/Publications/Papers-and-Statistics

Kolbe, T., Steele, C., & White, B. (2020). Time to teach: Instructional time and science teachers' use of inquiry-oriented instructional practices. *Teachers College Record, 122*(12), 1-54. https://doi.org/10.1177/016146812012201211

Krajcik, J., Schneider, B., Miller, E. A., Chen, I.-C., Bradford, L., Baker, Q., Bartz, K., Miller, C., Li, T., Codere, S., & Peek-Brown, D. (2023). Assessing the effect of project-based learning on science learning in elementary schools. *American Educational Research Journal, 60*(1), 70-102. https://doi.org/10.3102/00028312221129247

Krepf, M., Plöger, W., Scholl, D., & Seifert, A. (2018). Pedagogical content knowledge of experts and novices-what knowledge do they activate when analyzing science lessons? *Journal of Research in Science Teaching, 55*(1), 44–67. https://doi.org/10.1002/tea.21410

Kruse, J. W., Wilcox, J., & Menke, L. (2020). Changes in elementary teachers' conceptions about matter. *Journal of College Science Teaching, 50*(2), 49–57. https://doi.org/10.1080/0047231x.2020.12290684

Lambert, M. (2012). *A beginner's guide to doing your education research project*. SAGE Publications.

Lee, O. (2017). Common Core State Standards for ELA/literacy and Next Generation Science Standards. *Educational Researcher, 46*(2), 90–102. https://doi.org/10.3102/0013189X17699172

Lee, T. D., & Glass, B. (2019). Developing the next generation of elementary science teachers. *Journal of College Science Teaching, 49*(2), 18–23. https://doi.org/10.2505/4/jcst19_049_02_18

Lesseig, K., Slavit, D., Nelson, T. H., & Seidel, R. A. (2016). Supporting middle school teachers' implementation of STEM design challenges. *School Science & Mathematics, 116*(4), 177–188. https://doi.org/10.1111/ssm.12172

Lilly, S., McAlister, A. M., Fick, S. J., Chiu, J. L., & McElhaney, K. W. (2022). Elementary teachers' verbal supports of science and engineering practices in an NGSS-aligned science, engineering, and computational thinking unit. *Journal of Research in Science Teaching, 59*(6), 1035–1064.

https://doi.org/10.1002/tea.21751

Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative Research Journal, 19*(3), 259–270. https://doi.org/10.1108/QRJ-12-2018-0012

Lottero-Perdue, P. S., & Parry, E. A. (2017). Perspectives on failure in the classroom by elementary teachers new to teaching engineering. *Journal of Pre-College Engineering Education Research, 7*(1), 47–67. https://doi.org/10.7771/2157-9288.1158

Lowell, B. R., Cherbow, K., & McNeill, K. L. (2021). Redesign or relabel? How a commercial curriculum and its implementation oversimplify key features of the NGSS. *Science Education, 105*(1), 5–32. https://doi.org/10.1002/sce.21604

Lowell, B. R., McGowan, H. (2022). Using key features to analyze and modify curriculum for the NGSS. *Science Scope*, *45*(3), 48–54. https://doi.org/10.1080/08872376.2022.12291458

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. *Examining Pedagogical Content Knowledge*, 95–132. https://doi.org/10.1007/s10972-013-9341-4

Mahfouz, J., Sausner, E., & Kornhaber, M. (2019). US international schools overseas and the Common Core. *International Journal of Leadership in Education, 22*(4), 406-420. https://doi.org/10.1080/13603124.2018.1481529

Mathis, C. A., Siverling, E. A., Glancy, A. W., & Moore, T. J. (2017). Teachers' incorporation of argumentation to support engineering learning in STEM integration curricula. *Journal of Pre-College Engineering Education Research, 7*(1), 76–89. https://doi.org/10.7771/2157-9288.1163

Matsumoto, A. (2019). Literature review on education reform in the UAE. *International Journal of Educational Reform, 28*(1), 4–23. https://doi.org/10.1177/1056787918824188

McFadden, J. (2019). Transitions in the perpetual beta of the NGSS: One science teacher's beliefs and attempts for instructional change. *Journal of Science Teacher Education, 30*(3), 229–258. https://doi.org/10.1080/1046560X.2018.1559559

McNeill, K. L., Affolter, R., & Clinchot, M. (2021). Shifting from learning about to figuring out: PD resources to support classroom change. *Science Scope, 45*(2), 12. https://doi.org/10.1080/08872376.2021.12291445

Meredith, A. (2019). Terry's learning: Some limitations of Shulman's pedagogical content knowledge. *Cambridge Journal of Education, 25*(2), 175–188. https://doi.org/10.1080/0305764950250205

Merritt, E. G., Chiu, J., Peters-Burton, E., & Bell, R. (2018). Teachers' integration of scientific and engineering practices in primary classrooms. *Research in Science Education, 48*(6), 1321–1337. https://doi.org/10.1007/s11165-016-9604-0

Miller E. A., Berland, L. & Campbell, T. (2023). Equity for students requires equity for teachers: The inextricable link between teacher professionalization and equity-centered science classrooms. *Journal of Science Teacher Education,* 1–20. https://doi.org/10.1080/1046560X.2023.2170793

Mohamed, M., & Morris, P. (2019). Buying, selling and outsourcing educational reform: The global education industry and 'policy borrowing' in the gulf. *Compare: A Journal of Comparative and International Education.* https://doi.org/10.1080/03057925.2019.1607255

Moreno, N. P. (1999). K-12 science education reform- A primer for scientists. *BioScience, 49*(7), 569–576.

Morgan, C., & Ibrahim, A. (2019). Configuring the low performing user: PISA, TIMSS and the United Arab Emirates. *Journal of Education Policy*, https://doi.org/10.1080/02680939.2019.1635273

National Academies of Sciences, Engineering, and Medicine. (2016). *Science teachers learning: Enhancing opportunities, creating supportive contexts*. The National Academies Press. https://nap.nationalacademies.org/catalog/21836/science-teachers-learning-enhancing-opportunities-creating-supportive-contexts

National Academies of Sciences, Engineering, and Medicine. (2018). *Design, selection, and implementation of instructional materials for the Next Generation Science Standards: Proceedings of a workshop*. The National Academies Press. https://doi.org/10.17226/25001

National Academies of Sciences, Engineering, and Medicine. (2022). *Science and Engineering in Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators*. The National Academies Press. https://doi.org/10.17226/26215

National Research Council. (2012). *A framework for K-12 science education: Practices,* *crosscutting concepts, and core ideas*. The National Academies Press. https://nap.nationalacademies.org/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts

National Research Council. (2015). *Guide to implementing the Next Generation Science Standards*. The National Academies Press. https://doi.org/10.17226/18802.

National Science Teacher Association. (2014a). *About the Next Generation Science Standards*. https://ngss.nsta.org/About.aspx

National Science Teacher Association. (2014b). *Science and engineering practices*. https://ngss.nsta.org/PracticesFull.aspx

Nawafleh, M. K. & Jaradat. A. F. (2022). The degree to which kindergarten teachers in Jordan possess scientific and engineering practices in light of the Next Generation Science Standards (NGSS). *دراسات: العلوم التربوية*, *49*(3). https://doi.org/10.35516/edu.v49i3.1943

NGSS Lead States. (2013a). *Next Generations Science Standards: For states, by states*. National Academies Press. https://nap.nationalacademies.org/catalog/18290/next-generation-science-standards-for-states-by-states

NGSS Lead States. (2013b). *Next Generation Science Standards: For states, by states (Why K-12 science standards matter?)*. https://www.nextgenscience.org/resources/why-k-12-standards-matter

NGSS Lead States. (2013c). *Next Generation Science Standards: For states, by states (Three-dimensional learning)*. https://www.nextgenscience.org/three-dimensions

NGSS Lead States. (2016). *NGSS lesson screener: A quick look at potential lesson* *design*. https://www.nextgenscience.org/sites/default/files/NGSSScreeningTool-2.pdf

Nollmeyer, G. E., & Bangert, A. W. (2017). Measuring elementary teachers' understanding of the NGSS framework: An instrument for planning and assessing professional development. *Electronic Journal of Science Education, 21*(8), 20–45.

Novak, A. M., Hubbard, P., Ebeling, B., & Maher, B. (2016). Explanations across the curricula: Integrating Common Core State Standards in literacy with the Next Generation Science Standards. *Science Scope, 39*(8), 54–60. https://doi.org/10.2505/4/ss16_039_08_54

Organisation for Economic Co-operation and Development. (2012). PISA 2012 results: What 15-year-olds know and what they can do with what they know?. https://www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf

Organisation for Economic Co-operation and Development. (2019). PISA 2018: Insights and interpretations. https://www.oecd.org/pisa/publications/pisa-2018-results.htm

Osborne, J., Rafanelli, S., & Kind, P. (2018). Toward a more coherent model for science education than the crosscutting concepts of the next generation science standards: The affordances of styles of reasoning. *Journal of Research in Science Teaching, 55*(7), 962–981. https://doi.org/10.1002/tea.21460

Pasley, J. D., Trygstad, P. J., & Banilower, E. R. (2016). *What does "Implementing the NGSS" mean? Operationalizing the science practices for K-12 classrooms*. Horizon Research, Inc. https://files.eric.ed.gov/fulltext/ED587212.pdf

Patton, M. Q. (2002). *Qualitative interviewing: Qualitative research and evaluation* *methods*. SAGE Publications, Inc.

Pennington, R. (2017). American curriculum schools top choice for UAE parents, ADEC says. *The National*. https://www.thenationalnews.com/uae/american-curriculum-schools-top-choice-for-uae-parents-adec-says-1.224827

Penuel, W. R., Harris, C. J., & DeBarger, A. H. (2015). Implementing the Next Generation Science Standards. *Phi Delta Kappan, 96*(6), 45–49. https://doi.org/10.1177/0031721715575299

Pleasants, J., & Olson, J. K. (2019). Refining an instrument and studying elementary teachers' understanding of the scope of engineering. *Journal of Pre-College Engineering Education Research, 9*(2), 1–18. https://doi.org/10.7771/2157-9288.1207

Plumley, C. L. (2019). *2018 NSSME+: Status of elementary school science*. Horizon Research, Inc. https://horizon-research.com/NSSME/wp-content/uploads/2019/05/2018-NSSME-Status-of-Elementary-Science.pdf

Post, T., & Van Der Molen, J. W. (2020). Effects of a longitudinal school development program on primary teachers' attitudes toward inquiry teaching and their inquiry teaching practices. *Teachers College Record, 22*(120315), 1–62. https://doi.org/10.1177/016146812012201215

Rachmawati, E., Prodjosantoso, A. K., & Wilujeng, I. (2019). Next Generation Science Standard in science learning to improve student's practice skill. *International Journal of Instruction, 12*(1), 299–310. https://doi.org/10.1177/016146812012201215

Ravitch, S. M., & Carl, N. M. (2016). *Qualitative research: Bridging the conceptual, theoretical, and methodological*. Sage Publication, Inc.

Reiser, B. J., Michaels, S., Moon, J., Bell, T., Dyer, E., & Edwards, K. D., McGill, T. A., Novak, M., & Park, A. (2017). Scaling up three-dimensional science learning through teacher-led study groups across a state. *Journal of Teacher Education, 68*(3), 280–298. https://doi.org/10.1177/0022487117699598

Ridge, N., Kippels, S., & Shami, S. (2015a). Private education in the United Arab Emirates and Qatar: Implications and challenges. *Sheikh Saud Bin Saqr Al Qasimi Foundation for Policy Research Working Paper No. 8*. https://doi.org/10.18502/aqf.0113

Ridge, N., Kippels, S., Shami, S., & Farah, S. (2015b). Who benefits from private education in the UAE and Qatar?. *Sheikh Saud Bin Saqr Al Qasimi Foundation for Policy Research Policy Paper No. 13*. https://doi.org/10.18502/aqf.0033

Rose, M. A., Carter, V., Brown, J., & Shumway, S. (2017). Status of elementary teacher development: Preparing elementary teachers to deliver technology and engineering experiences. *Journal of Technology Education, 28*(2), 2–18. https://doi.org/10.21061/jte.v28i2.a.1

Roseman, J. E., Herrmann-Abell, C. F., & Koppal, M. (2017). Designing for the Next Generation Science Standards: Educative curriculum materials and measures of teacher knowledge. *Journal of Science Teacher Education, 28*(1), 111–141. https://doi.org/10.1080/1046560X.2016.1277598

Saldaña, J. (2016). *The coding manual for qualitative researchers* [3rd ed]. SAGE

Publications Inc.

Sawchuk, S. (2018). Is STEM oversold as a path to better jobs?. *Education Week, 37*(32), 16–19. https://www.edweek.org/ew/articles/2018/05/23/is-stem-oversold-as-a-path-to.html

Seung, E., Park, S., Kite, V., & Choi, A. (2023). Elementary preservice teachers' understandings and task values of the science practices advocated in the NGSS in the US. *Education Sciences, 13*(4), 371. https://doi.org/10.3390/educsci13040371

Shelton, T. (2021). Commentary: Developing NGSS-designed instructional materials with teachers "At the table." *Journal of Science Teacher Education, 32*(7), 852–857. https://doi.org/10.1080/1046560X.2021.1942640

Shernoff, D. J., Sinha, S., Bressler, D. M., & Schultz, D. (2017). Teacher perceptions of their curricular and pedagogical shifts: Outcomes of a project-based model of teacher professional development in the Next Generation Science Standards. *Frontiers In Psychology, 8*, 989. https://doi.org/10.3389/fpsyg.2017.00989

Shmidt, W. H., Wang, H. C., & McNight, C. C. (2005). Curriculum coherence: An examination of US mathematics and science content standards from an international perspective. *Journal of Curriculum Studies, 37*(5), 525–559. https://doi.org/10.1080/0022027042000294682

Short, J. B. (2006). *Teaching science in the 21st century*. National Science Teaching Association.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching.

Educational Researcher, 15(2), 4–14. https://www.jstor.org/stable/1175860

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

Smith, P. S. (2020). *Obstacles to and progress toward the vision of the NGSS*. Horizon Research, Inc. https://horizon-research.com/NSSME/wp-content/uploads/2020/04/NGSS-Obstacles-and-Progress.pdf

Special Report: Education. (2012). *Middle East Economic Digest (MEED)*, *19*, 41.

Spires, H. A., Himes, M. P., & Krupa, E. (2022). Supporting students' science content knowledge and motivation through project-based inquiry (PBI) global in a cross-school collaboration. *Education Sciences, 12*(6), 412. https://doi.org/10.3390/educsci12060412

Suh, J. K., & Park, S. (2017). Exploring the relationship between pedagogical content knowledge (PCK) and sustainability of an innovative science teaching approach. *Teaching and Teacher Education, 64,* 246–259. https://doi.org/10.1016/j.tate.2017.01.021

Talanquer, V. (2019). Crosscutting concepts as productive ways of thinking. *The Science Teacher*, (2), 16. https://doi.org/10.2505/4/tst19_087_02_16

Tuttle, N., Kaderavek, J., Molitor, S., Czerniak, C., Johnson-Whitt, E., & Bloomquist, D., Wilson, G. (2016). Investigating the impact of NGSS-aligned professional development on prek-3 teachers' science content knowledge and pedagogy. *Journal of Science Teacher Education, 27*(7), 717–745.

https://doi.org/10.1007/s10972-016-9484-1

UAE Ministry of Education. (2021). *Institutional policy no.50 for the year 2021*. https://www.moe.gov.ae/En/Legislation/Documents/50-2021.pdf

Wendell, K. B., Wright, C. G., & Paugh, P. (2017). Reflective decision-making in elementary student's engineering design. *Journal of Engineering Education, 106*(3), 356–397. https://doi.org/10.1002/jee.20173

Whitworth, B. A., & Wheeler, L. B. (2017). Is it engineering or not? To bring engineering tasks into the classroom, know what qualifies and what doesn't. *Science Teacher, 84*(5), 25–29.

Windschitl, M. A., & Stroupe, D. (2017). The three-story challenge: Implication of the Next Generation Science Standards for teacher preparation. *Journal of Teacher Education, 68*(3), 251–261. https://doi.org/10.1177/0022487117696278

Wright, D. S., Balgopal, M. M., Sample McMeeking, L. B., & Weinberg, A. E. (2019). Developing resilient K-12 STEM teachers. *Advances in Developing Human Resources, 21*(1), 16–34. https://doi.org/10.1177/1523422318814483

Wong, J. T., Bui, N. N., Fields, D. T. & Hughes, B. S. (2023). A learning experience design approach to online professional development for teaching science through the arts: Evaluation of teacher content knowledge, self- efficacy and STEAM perceptions. *Journal of Science Teacher Education, 34*(6), 593-623. https://doi.org/10.1080/1046560X.2022.2112552

Yang, Y., Liu, X., & Gardella, J. A. (2018). Effects of professional development on teacher pedagogical content knowledge: Inquiry teaching practices, and student understanding of interdisciplinary science. *Journal of Science Teacher Education, 29*(4), 263–282. https://doi.org/10.1080/1046560X.2018.1439262

Yesilyurt, E., Deniz, H., & Kaya, E. (2021). Exploring sources of engineering teaching self-efficacy for pre-service elementary teachers. *International Journal of STEM Education, 8*(1), 1–15. https://doi.org/10.1186/s40594-021-00299-8

Yin, R. K. (2009). *Case study research: Design and methods* (5th edition). Sage Publications.

Appendix A: Interview Protocol

Opening Remarks

Thank you accepting to be a volunteer in my doctoral research. My name is Zoya Houjeiri. I currently work as an educational consultant, and I am pursuing my Doctorate degree in Curriculum, Instruction, and Assessment at Walden University.

This interview should last about 45 min, and with your permission, I will be audio recording our conversation so that I can transcribe the words verbatim when the interview is over.

The purpose of my study is to better understand how elementary teachers use pedagogical content knowledge and curricular knowledge to implement instructional practices that integrate the three dimensions of NGSS when teaching science at American private schools in the UAE.

The findings of the study will be published when my dissertation is completed.

I already have your signed consent form to participate in this study.

Before we start, I would like to go over few important points:

- If you choose to terminate this interview, you can excuse yourself at any time and for any reason.
- You have the full right to withdraw from the study at any time.
- I have assigned a pseudonym to identify you, but there will be no reference to your name nor an identification in any of the notes, discussions, conversations or published documents related to the study.

- I will send you the complete transcript of the interview to provide your comments regarding the content and accuracy of the data.
- Is there any question or remark that you would like to share before we begin?

Please tell me a little about yourself and your job as a teacher.

I will start the interview now.

Upon your consent, I would like to start recording.

Background Information

How long have you been teaching science?

How many years of experience do you have in teaching NGSS?

Are you currently a science teacher?

Which grade level do you teach?

Interview Questions for Teachers

1. When were you introduced to the Next Generation Science Standards?
2. How do you describe the Next Generation Science Standards?
3. What do you think is the biggest change in your teaching practices when implementing the Next Generation Science Standards?
4. Which topics were new to you when you taught the Next Generation Science Standards?
5. How do you prepare when you are teaching a topic that is new to you?
6. How do you decide on which practices to use when teaching a particular topic?
7. Which practices do you find the most effective for teaching the three dimensions?
8. Do you use different instructional practices with different topics?

9. Do you think all practices can fit for teaching all the domains of science? Can you please give specific examples?
10. Do you feel anything is lacking in your science teaching? If so, please discuss.
11. Do you have any questions or concerns?

[1]Appendix B: Observation Protocol

NGSS Lesson Screener

A Quick Look at Potential NGSS Lesson Design

Introduction

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

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

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

Using the NGSS Lesson Screener: A Quick Look at Potential NGSS Design

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

While it is possible for the rubric to be applied by an individual, **the quality review process works best with a team of reviewers as a collaborative process**. Just as when using the full EQuIP Rubric for Science, users should:

1) individually record criterion-based evidence,
2) individually make suggestions for improvement, and then
3) collaboratively discuss findings with team members before checking one of the boxes under the "Evidence of Quality?" column. A rating of "Adequate" means that the lesson meets the criterion.

Working as a group will not only result in a better lesson, but can also bring the group to a common and deeper understanding of designing lessons for the NGSS.

Published December 2016

[1] From *NGSS Lesson Screener: A Quick Look at Potential NGSS Lesson Design* (pp. 3–9), by Next Generation Science Standards, 2016, Achieve & National Science Teachers Association (https://www.nextgenscience.org/sites/default/files/NGSSScreeningTool-2.pdf). CC BY.

NGSS Lesson Screener

A Quick Look at Potential NGSS Lesson Design for Instruction and Assessment

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

NGSS Shifts

A. **Explaining Phenomena or Designing Solutions**: The lesson focuses on supporting students to make sense of a phenomenon or design solutions to a problem.

B. **Three Dimensions**: The lesson helps students develop and use multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs), which are deliberately selected to aid student sense-making of phenomena or designing of solutions.

C. **Integrating the Three Dimensions for Instruction and Assessment:** The lesson requires student performances that integrate elements of the SEPs, CCCs, and DCIs to make sense of phenomena or design solutions to problems, and the lesson elicits student artifacts that show direct, observable evidence of three-dimensional learning.

Features of Quality Design

D. **Relevance and Authenticity:** The lesson motivates student sense-making or problem-solving by taking advantage of student questions and prior experiences in the context of the students' home, neighborhood, and community as appropriate.

E. **Student Ideas:** The lesson provides opportunities for students to express, clarify, justify, interpret, and represent their ideas (i.e., making thinking visible) and to respond to peer and teacher feedback.

F. **Building on Students' Prior Knowledge**: The lesson identifies and builds on students' prior learning in all three dimensions in a way that is explicit to both the teacher and the students.

Criterion A. Explaining Phenomena or Designing Solutions

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

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

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

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

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

Published December 2016

Criterion B. Three Dimensions

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

* The term "element" indicates the bulleted DCIs, SEPs, and CCCs that are articulated in the foundation boxes of the standards. These elements are summarized in NGSS Appendices F & G for the SEPs and CCCs and *NSTA's DCI matrix for the DCIs. (Note that NGSS Appendix E contains summaries of the DCIs—not the DCI elements).*

	NGSS designed lessons will look *less* like this:	NGSS designed lessons will look *more* like this:
Three Dimensions	A single practice element shows up in the lesson.	The lesson helps students use multiple (e.g., 2–4) practice elements as appropriate in their learning.
	The lesson focuses on colloquial definitions of the practice or crosscutting concept names (e.g., "asking questions", "cause and effect") rather than on grade-appropriate learning goals (e.g., elements in NGSS Appendices F &G).	Specific grade-appropriate elements of SEPs and CCCs (from NGSS Appendices F & G) are acquired, improved, or used by students to help explain phenomena or solve problems during the lesson.
	The SEPs and CCCs can be inferred by the teacher (not necessarily the students) from the lesson materials.	Students explicitly use the SEP and CCC elements to make sense of the phenomenon or to solve a problem.
	Engineering lessons focus on trial and error activities that don't require science or engineering knowledge.	Engineering lessons require students to acquire and use elements of DCIs from physical, life, or Earth and space sciences together with elements of DCIs from engineering design (ETS) to solve design problems.

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

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

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

Criterion C. Integrating the Three Dimensions for Instruction and Assessment

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

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

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

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

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

Criterion D. Relevance and Authenticity

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

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

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

Lessons designed for the NGSS include clear and compelling evidence of the following:	What was in the materials, where was it, and why is this evidence?	Evidence of Quality?	Suggestions for improvement
D. Relevance and Authenticity: The lesson motivates student sense-making or problem-solving by taking advantage of student questions and prior experiences in the context of the students' home, neighborhood, and community as appropriate.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	

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

Criterion E. Student Ideas

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

	NGSS designed lessons will look *less* like this:	NGSS designed lessons will look *more* like this:
Student Ideas	The teacher is the central figure in classroom discussions.	• Classroom discourse focuses on explicitly expressing and clarifying student reasoning • Students have opportunities to share ideas and feedback with each other directly.
	Student artifacts only show answers.	Student artifacts include elaborations (which may be written, oral, pictorial, and kinesthetic) of reasoning behind their answers, and show how students' thinking has changed over time.
	The teacher's guide focuses on what to tell the students.	The lesson provides supports to teachers for eliciting student ideas.

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

Lessons designed for the NGSS include clear and compelling evidence of the following:	What was in the materials, where was it, and why is this evidence?	Evidence of Quality?	Suggestions for improvement
E. Student Ideas: The lesson provides opportunities for students to express, clarify, justify, interpret, and represent their ideas (i.e., making thinking visible) and to respond to peer and teacher feedback.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	

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

Criterion F. Building on Students' Prior Knowledge

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

	NGSS designed lessons will look *less* like this:	NGSS designed lessons will look *more* like this:
Building on Students' Prior knowledge	The lesson content builds on students' prior learning, but only for DCIs.	The lesson content builds on students' prior learning in all three dimensions.
	The lesson does not include support to teachers for identifying students' prior learning.	The lesson provides explicit support to teachers for identifying students' prior learning and accommodating different entry points, and describes how the lesson will build on the prior learning.
	The lesson assumes that students are starting from scratch in their understanding.	The lesson explicitly works together with students' foundational knowledge and practice from prior grade levels.

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

Lessons designed for the NGSS include clear and compelling evidence of the following:	What was in the materials, where was it, and why is this evidence?	Evidence of Quality?	Suggestions for improvement
F. Building on Students' Prior Knowledge: The lesson identifies and builds on students' prior learning <u>in all three dimensions</u> in a way that is explicit to both the teacher and students.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	

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

NGSS Lesson Screener: A Quick look at NGSS Lesson Design

Reviewer Name or ID: ________________________________ **Grade:** ________ **Lesson/Unit Title:** ____

Reminder: The purpose of the NGSS Lesson Screener is to give a quick look at a lesson. There are significant aspects of what would be expected in a fully-vetted NGSS-designed lesson that are not addressed in this tool and it should not be used to fully vet resources or claim that the lessons are designed for NGSS. Refer to the *EQuIP Rubric for Lessons & Units: Science*, or the Primary Evaluation of Essential Criteria (PEEC) for full evaluations.

Overall Screening Summary:

Appendix C: List of Open Codes Retrieved From NVivo

Category (code)	No. of files	No. of references
Changes in teaching	8	23
New way of teaching science	4	6
Exploring science	3	3
Innovation	1	1
Use the 5Es	1	1
Using cross-curricular connections	2	3
Student-centered approaches	7	9
Students develop knowledge	3	3
Students develop practices	3	5
Integrating pedagogical knowledge and curricular knowledge	10	30
Pedagogical knowledge	5	5
New content	2	2
New topic earth and space	1	1
New topic engineering and technology	1	1
No new topics	3	3
No challenges	6	6
No concerns	8	8
Reason for practices choice	8	37
Choice of practice	4	4
Focus on content	2	2
ELL students	3	4
Simplifying	3	6
Focus on inquiry	2	2
Developing critical thinking skills	1	1
Hands on	5	8
Investigations	3	4
Modeling	2	2
PBL	2	3

Category (code)	No. of files	No. of references
Reflection	1	1
Not all practices work for all domains	5	9
Resources	6	9
Doing research	1	1
Use of teacher guide	4	7
Use of external websites	5	9
Use of visuals	2	3
Use of worksheets	2	2
Three-dimensional standards	8	12
Challenges	4	22
Lack of resources	3	3
Need more time	2	6
Student level	3	10
Describing NGSS	10	10
Experience	9	12
3-5 years of experience	3	3
More than 5 years of experience	7	8
Focusing on three dimensions	3	4

Note. 5E = engage, explore, explain, extend, and evaluate model; ELL = English Language Learner; PBL = project-based learning; NGSS = Next Generation Science Standards.