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The Use of Instructional Materials in Elementary Science Classrooms

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Abstract

This mixed methods study explored how elementary teachers reported using a commercially published instructional unit to plan and deliver science instruction in their elementary classrooms. Of particular focus is what elements of the program teachers eliminated during planning and instruction, what outside materials teachers added to instruction, what modifications they made to the materials, and their rationales for these changes to the prescribed program.

This study consisted of two phases. The first was a survey of elementary science teachers who taught the *Smithsonian Science for the Classroom* units. Data collected from this phase informed the subsequent interview phase. I used deductive coding to analyze the data and a descriptive narrative format to report the findings and implications of this study to answer the following questions: How do teachers report using instructional materials in elementary science during the planning and delivery of instruction? What modifications, if any, do teachers report making to instructional materials? What rationales do teachers report for their modifications?

Two clear themes emerged from the study. First, teachers eliminated lessons and shortened tasks to fit instruction into the minutes designated for teaching science. Time constraints or the perception by teachers that the tasks would be too difficult for their students were typical rationales given for making any changes to the materials.

Implications for teachers, administrators, professional development providers, and policymakers were discussed.

Keywords: elementary science teaching, science teaching, science education reform, science instructional materials, science kits

The Use of Instructional Materials in Elementary Science Classrooms

by

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Chapter One

Calls for science education reforms have occurred since the 1800s, mainly occurring in cycles until the 1950s, after which the calls to reform science education in the United States have been continuous. Reform efforts were spurred on by major events such as the launching of Sputnik by the Soviets, interpreted as a reflection of an unprepared US to lead international accomplishments in space. Other efforts reflected a more socially responsive movement, such as environmentalism, which began in earnest after World War Two when the concerns were pollution and the conservation of nature. The book *Silent Spring*, published in 1962 by environmentalist Rachel Carson, brought attention to the dangers of pesticides, specifically DDT, and warned that industrialization and technological advances promised to be disastrous to the earth and human health if the path continued. Carson's book highlighted the negative aspects of human technological developments. The book drew the attention of millions and contributed to adding a more robust environmental education emphasizing scientific literacy in the science curriculum in schools. However, given the economic, social, and cultural components of current ecological issues, such as climate change and global warming, controversies continue to exist regarding what should be included in environmental education (Stein, 2014; Clark et al., 2020).

Recent efforts in science education reform have focused on meeting the needs of the workforce, focusing on STEM careers, and providing equitable learning opportunities for all students. (DeBoer, 2014; NRC, 2012). However, these efforts have not closed the gap between white, Black, and Native American students, diversified the STEM professions, increased high school graduation rates, or improved science literacy (NRC, 2012; US Dept. of Education, 2015).

The 2019 National Assessment of Educational Progress (NAEP), a national assessment that measures students' knowledge and abilities in various academic areas, notes that in science, students in grade four scored two points lower than in 2015, and eighth-grade scores showed no significant change. The 2018 Programme for International Student Assessment (PISA), an international measurement of student achievement in reading, math, and science, shows that American students still lag behind students in other nations in science knowledge and abilities.

The US currently finds itself in yet another iteration of reform, notably the adoption or state-based adaptation of the Next Generation Science Standards (NGSS). The standards specify broad science ideas identified in the *Framework for K-12 Science Education* (hereafter known as the Framework). The standards provide new measures to create equitable opportunities for obtaining science and engineering knowledge to help students participate more fully in our complex world (NRC, 2012). Issues that grip our nation and our world, such as climate change and the global pandemic, remind us that creating a scientifically literate population who can meet today's challenges and create solutions backed by science is crucial. Scientific literacy is implied in the NGSS and emphasizes the ability to engage with science-related issues and ideas of science with meaningful discourse as a reflective citizen (Roberts & Bybee, 2014). To this end, scientific literacy requires content, procedural, and epistemic knowledge of science (OECD, 2019). Therefore, school science programs should provide opportunities for students to engage in practices where they learn science concepts and "how scientific knowledge is developed, validated, and communicated" (Park, 2022, p. 562).

During the review of these standards, scholars point out that they do not go far enough to promote environmental justice, especially in communities of color (Morales-Doyle et al., 2019). For example, the creation of the NGSS was sponsored in part by the Dupont Corporation, a leading producer of paint containing lead and other toxins, which disproportionately accumulate in the ground and water of regions that are home to communities of color. The standards do not mention this, instead suggesting the chemistry education and enviornmental education present these chemicals as neutral, rather than having negative impacts on communities. Though perhaps not perfect, they present more opportunities in terms of equity and accessibility for all students than previous standards.

These standards have been adopted or adapted by 44 states and the District of Columbia, requiring increased attention to ensure that the NGSS successfully meets the Framework's goals. How can we move science education forward so that this attempt at providing quality science education for all students does not result in another failed reform attempt? Research suggests that a critical component in the success or failure of any reform effort lies with the classroom teacher (Ball & Cohen, 1996; Remillard, 2005; Brown, 2011; NAP, 2012; NAP, 2015). However, research also suggests that more information is needed to fully understand the nuances of classroom-level science teaching (Zangori et al., 2013; DeBarger et al., 2016). Now that the standards have been released for nearly a decade, giving teachers some time to become familiar with them, and districts have had the opportunity to rectify any delays in implementing standards-aligned instructional materials caused by the COVID pandemic, research that focuses on classroom-level science instruction seems timely and prudent. It is time to get a sense of where things stand at the classroom level and determine what is needed to allow this reform effort to move forward. We need to close the gaps in science education opportunities between white and underserved populations, improve science literacy for all students, diversify the STEM fields, and address the professional development needs of teachers tasked with this complex undertaking. Understanding what is happening at the classroom level during science lesson planning and instruction is essential to keep this effort moving toward the vision of the standards as presented in the Framework. This study will examine how classroom teachers report using instructional materials to plan and carry out science instruction in elementary classrooms.

Context of the Problem

Several science reform efforts of note since the mid-nineteenth century have focused on putting science students in direct contact with phenomena and having them reason through trends and patterns that emerge. By the first half of the 20th century, a long period of progressive era reforms, heightened by social activism, focused on a desire to rebuild the country after the Great Depression and educate and lead a large influx of immigrants to the American way of life.

The launching of the spacecraft Sputnik in 1957 by the Russians, an act perceived by some as a failure by America's science community to beat the Russians into space, began an earnest effort to improve science education. Funded by the National Science Foundation, many curriculum projects such as summer institutes for college science instructors emerged to encourage a rigorous science curriculum. Eventually, these programs were expanded to include high school teachers as well (NSF, 1994). It is important to note that throughout the reform efforts through these decades and into the next few, the focus emphasized educating college-bound white males, despite the increase in the number of women and people of color attending college in the sixties and seventies (DeBoer, 2014).

In reaction to this era's highly discipline-focused, and rigorous curriculum came a wave of reform efforts focused on social responsibility. The shift from the focus on the individual to social activism, such as environmental awareness, reflected societal views of the then-president Reagan era.

A 1983 report by the Commission on Excellence in Education, *A Nation at Risk*, noted that American schools still failed to keep pace with other nations (US Department of Education, 2008). This report, criticized by some as citing statistics that supported the writers' position while ignoring or falsely reporting those that did not, is still one of the most quoted reports on the state of education in the US. Shortly after *A Nation at Risk* was published, educational researcher Paul Hurd concluded at the end of a thorough national survey of student achievement, "We are raising a new generation of Americans that are scientifically and technologically illiterate." (US Dept of Education: Archive, 1983). In a similar vein, John Slaughter, a former Director of the National Science Foundation, warned of "a growing chasm between a small scientific and technological elite and a citizenry ill-informed, indeed uninformed, on issues with a science component" (National Commission on Excellence in Education, 1983).

Recommendations from these reports included providing a more rigorous curriculum and the development of "rigorous state standards that challenge students to do better and graduate smarter" (National Commission on Excellence in Education, 1983). The importance of this era can not be understated, as this was the beginning of state standards-based instruction which provides the basis for education in America today.

Specifically focused on science, math, and technology instruction, and published closely behind *A Nation at Risk,* work began on Project 2061, a report issued by the American Association for the Advancement of Science, entitled *Science for All Americans*, and its follow-up publication, *Benchmarks for Science Literacy.* Commencing in 1985, the year Halley's Comet passed by Earth, Project 2061 developers realized that students who would be well into their adulthood when Halley’s Comet passed in 2061, would soon be starting school. The developers looked to the future to improve science literacy for all Americans by the time Halley's Comet passed Earth again in 2061. Part of the transition from *A Nation at Risk* to Project 2061 was to broaden science instruction for the general population. Further, developers noted that "the present curricula in science and math are overstuffed and undernourished" and "fails to encourage students to work together, share ideas, and use modern instruments to extend their intellectual capabilities." (Rutherford & Ahlgren, 1990, p. xii). Project 2061 emphasized curriculum reform that shaped lasting knowledge and skills students should have by the time they become adults, centered on all children and specified thresholds, not advanced performance (AAAS, 1993). Project 2061 was designed in three phases, the first focused on the substance of science literacy, or what constitutes science literacy. In the second phase developers created curricular models to be used in schools, when delivering professional development, and when creating policy. The third phase was the longest, lasting a decade or more, and was meant to encourage widespread collaboration using findings from phases one and two to reform science education.

Recommendations for all students K-12 were reported in the Project 2061 document *Science For All Americans* and included a broad definition of science literacy and more specific recommendations for topics of study based on ideas and skills that had the greatest educational and scientific significance (AAAS, 1993). In 1993, a followup publication, *Benchmarks for Science Literacy* provided statements, or benchmarks, of what all students should be able to do in science, math, and technology at various intervals, grades 2, 5, 8, and 12, to make progress toward scientific literacy.

More than 20 years later, some components of previous reform efforts appear in the current effort, notably the Next Generation Science Standards (NGSS). These standards are K-12 standards designed to incorporate and integrate disciplinary core ideas, crosscutting concepts, and science and engineering practices. Following the Framework's recommendations, the NGSS are minimum standards of what all students should know and be able to do by the end of high school. In the vision of the NGSS, students work with real-world phenomena and understand science concepts through collaboration, data collection, modeling, and argumentation. Like Project 2061, the NGSS stress depth over breadth and set the floor instead of the ceiling for scientific knowledge. These standards, or a state's variation, create a sizeable break from traditional teaching strategies. Students learn science by "doing science" instead of the traditional classroom format where teachers dispense information and students perform "cookie-cutter" investigations with predetermined interpretations of the outcomes. Unlike previous standards, the NGSS offer grade-specific K-5 standards. Students learn core content, categorized in the NGSS as Disciplinary Core Ideas (DCI), by engaging in the real work of scientists, called Scientific and Engineering Practices (SEP), such as gathering and analyzing data and making evidence-based claims. The NGSS also promote a third component, the Crosscutting Concepts (CCC) such as structure and function and patterns that can be carried into many strands of science as well as other disciplines such as mathematics and language. Understanding science content (DCI) through participating in the work of scientists (SEP) helps students understand how we come to know what we know. Connecting themes across various strands of science (CCC) helps students see how the strands of science share certain components and how the strands are connected.

In addition to outlining what all students should know and be able to do, the NGSS emphasizes how the content, practices, and crosscutting concepts are incorporated beginning as early as kindergarten and extending through grade twelve. While some may still argue the futility of teaching science at the elementary level, research has rendered that notion outdated. Once seen as simplistic thinkers, research shows that children are much more capable than initially thought (NRC, 2007; NRC, 2012). Scientific literacy begins in early childhood, continues through elementary school, and takes years to develop.

> "Young children come to school with a great learning capacity and surprisingly can engage in sophisticated scientific thinking in the early grades. Children enter school with substantial knowledge of the natural world. They can reason in ways that provide the basis for scientific reasoning and can be built upon to develop scientific concepts" (NRC, 2007, p.52).

Building on children's natural curiosity, teaching science to students at a young age can create positive attitudes toward science, ultimately leading to an interest in pursuing STEM fields. The research about young children's ability to learn science is reflected in the elementary grade-specific standards of the NGSS beginning in kindergarten.

Instructional materials are available that align with the vision of teaching and learning science articulated in the NGSS from kindergarten to grade twelve where teachers act as guides and students ask and answer questions, collect and analyze data, and make claims based on evidence and reasoning (Lead States, 2013). This study focuses on how teachers from various districts across the United States use a common set of NGSS-aligned published instructional materials to plan and enact lessons to meet these standards.

Statement of the Problem

The implementation of the NGSS occurred when it was widely documented that districts across the US dedicated substantially less time to science instruction than other subjects, specifically mathematics and English Language Arts (Smith, 2020; NRC, 2012). Complying with state and local mandates focused in mathematics and ELA created additional demands on instructional time, leaving little time for science instruction. While states and districts often made decisions regarding adopting new research-based standards such as the NGSS, the classroom teacher was tasked with implementation at the classroom level. Instructional materials "have emerged as one of the key mechanisms for creating high-quality learning experiences for students" (National Academies of Science, Engineering and Medicine, 2018). While we know instructional materials are necessary, more understanding is needed about how they are used in the classroom. The goal of this study is to add to the literature about how teachers draw on instructional materials in planning and delivering science instruction in the elementary classroom, and aid in understanding what support teachers need to better serve students in learning science.

Numerous studies described the relationship between teachers and instructional materials as critical. For example, Brown (2009) described instructional materials as inert tools for instruction that only come to life through a practitioner. The National Survey of Science and Mathematics Education (NSSME+), funded by the National Science Foundation and conducted by Horizon Research, Inc. every six years, provided authoritative data on mathematics and science education in the US for the last 40 years. The NSSME+ reported on many facets of teaching science, such as frequency and duration of instruction, instructional objectives, activities, and instructional materials (Banilower et al., 2018). While the NSSME+ revealed what types of materials teachers report using in teaching science, some questions still need to be addressed. The NSSME+ did not supply data about their decisions concerning what modifications were made to materials or the rationale behind those decisions (Horizon Research Corp, 2019). This study addresses that gap. Of particular focii in this study are the modifications to instructional materials teachers make, and the rationale teachers present for making those modifications. Only when we understand what modifications teachers make and why, can we understand what supports teachers may need to support the instruction in greater alignment with the goals of the standards and the units.

While many elementary classrooms still use a textbook as the primary source of instruction, the 2018 NSSME+ reports that the use of kit materials, also known as modules, is on the rise. Sixteen percent of teachers reported using kit materials in 2012, vs. twenty-nine percent in 2018 (NSSME+ 2012; NSSME+ 2018).

Science kit materials include a teacher's manual, which guides teachers through the unit and typically contains a scope and sequence, content background information, lesson plans, and student notebook masters. Other resources in the kit include student readers and a supply of physical materials for a classroom of students to use when conducting investigations. This kit, therefore, supplies a "unit in a box" containing almost everything needed to teach and learn that unit. Like textbook publishers, kit material developers and distributors created materials to meet the standards of the NGSS, and some districts use these updated materials. How teachers use these updated materials in their classroom instruction requires more study. For example, some teachers follow the investigations closely, while others modify the lessons or materials. Some teachers use a combination of materials such as textbook readings and kit materials (Davis, 2016).

Significance of the Study

Before researchers can study the impact of modifications of instructional materials on student learning, more evidence is needed about trends and patterns that emerge in those modifications. Substitutions, additions, or deletions teachers make have the potential to improve student learning or limit opportunities for students to learn. Knowing what these are is significant in determining what, if any, supports teachers need, what edits might be considered for future editions of the materials, and most importantly, how student learning is affected. This study focused on how teachers approached planning and delivering science instruction, specifically on decisions they made to add material to the lessons, modify the materials, or delete material from the unit. I first surveyed fourth grade teachers using questions selected and adapted from the NSSME+. I then compared the responses from the survey to those recorded on the 2018 NSSME+. I looked for areas where the teachers in this study reported anything out of alignment with the 2018 NSSME+ responses.I then interviewed twelve survey respondents by phone. I analyzed the interviews for evidence of adherence to the units as written, changes to the units, and how those changes might affect cognitive demand, student opportunities to use scientific and engineering practices, and how these changes impact the standards. To this end, the following research questions were the focus of this study:

- How do teachers report using instructional materials in elementary science during the planning and delivery of instruction?
- What modifications, if any, do teachers report making to elementary science instructional materials?
- What rationales do teachers report for these modifications?

The overall significance of this study was to learn more about how teachers use instructional materials in elementary science classrooms. This information can then be used to determine what support teachers need to provide instruction, ultimately leading to better opportunities for students to learn science. Instructional materials exist that align with the NGSS, but more needs to be known about the use of those specific materials in planning and delivering instruction. The NSSME+ provides information about classroom-level instruction in a broad sense. For example, teachers in the NSSME+ report skipping material in science instruction due to time constraints. However, it does not interrogate what specific types of lessons or activities get eliminated or differentiate between what materials are used for instruction (textbooks, kits, or both) when teachers determine what to eliminate. This study contributes to the field's knowledge of more specific unit and lesson-related science teaching using standard-aligned instructional materials. Former educational innovations in science have partially failed because teacher enactment of reform materials did not match the developers' intentions (Young & Lee, 2005; Bismack et al., 2014). Understanding how teachers use science instructional materials at the classroom level lays the foundation for researchers to study how changes to those materials can impact student opportunities to learn, the goals of the NGSS, and science education reform more broadly. Additionally, understanding how teachers use the instructional materials at the classroom level can inform curriculum developers, professional developers, and preservice and in-service teachers, key stakeholders in the reform effort.

Role of the Researcher

The role of the researcher in any study is directly related to the type of research conducted. In this study, I hold some views in line with post-positivism. In post-positivism, researchers are concerned with bias and view themselves as independent of the study participants (Creswell, 2018; Merriam & Tisdell, 2015) but have concerns about researcher bias. My positions as a science lab instructor and science coach, familiarity with the SSEC materials, and strong beliefs about the value of quality science education for elementary students have certainly informed any bias I hold. Therefore, I needed to be aware of those biases in every step of this study. A mixed methods approach is reasonable for this reason. In a mixed methods research design, multiple perspectives are employed, thus making it less likely that researcher bias will influence data analysis.

I also hold views in line with constructivism. Constructivists believe that individuals form their realities from their lived experiences, unlike post-positivists, who believe there is a single reality that is unreachable (Creswell, 2018). In this study, I believe the participants have created their own reality based on several factors influencing their views on science teaching. Because of how teachers bring instructional materials to life (Brown, 2011) and the uniqueness of all individuals, no one reality is possible. Therefore, the goal of this study must be to understand each participant's reality.

Definitions

These terms will be used throughout this dissertation and are presented here for clarity and consistency.

Crosscutting Concepts (CCC): concepts that apply across all domains of science and link those domains. They include patterns; cause and effect, scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change (NRC, 2012).

Disciplinary Core Ideas (DCI): a limited set of ideas in science that allow for deep exploration of important concepts, e.g., matter, ecosystems, Earth's place in the universe, and energy (NRC, 2012).

Curriculum: knowledge and practices in subject matter areas that teachers teach, and students are supposed to learn. The curriculum includes the scope of the subject area and a sequence of concepts for learning (NRC, 2012).

Instructional Materials/Curriculum Materials: resources designed to support or supplement instruction, including textbooks, physical materials for use in investigations, curriculum guides, descriptions of tasks, and instructional software (Remillard & Heck, 2014).

Enactment: the performance of teaching (Remillard, 2005).

Professional Development: activities designed to engage in-service teachers in opportunities to learn about teaching and learning (King, 2016).

Science and Engineering Practices (SEP:) the processes that allow the construction of scientific knowledge, theories, and models using evidence and the communication of scientific knowledge through the construction of arguments in which scientists engage. These practices include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations (for science) and designing solutions (for engineering), engaging in argument from evidence, and obtaining, evaluating, and communicating information (Osborne, 2014, NRC, 2012).

Science Kit/Science Module: materials and lessons developed in a ready-to-teach format: kits typically include a teacher manual, readers for students, and physical materials to perform investigations; packages of materials, instructional resources, and structuring guidelines designed to shape the content, pacing, and often the processes and tools of instruction" (Houston et al., 2008; Remillard & Heck, 2014).

Standards: a K-12 progression of specific science-related goals of learning and expectations and of what students should know (content) and be able to do (practices) (Nextgenscience.org; NRC, 2012).

Teacher Manual: Digital or physical handbook designed to guide teachers through the instruction of a unit, often containing the scope and sequence of the topics, lessons of the unit, step-by-step lesson plans, copy masters for student notebooks, and often professional development material.

Chapter Overview

This study consists of five chapters. Chapter two contains a review of relevant literature. In this chapter, I begin by exploring the central tenets of science instruction as outlined in the Framework to assist the reader in understanding how the NGSS came about. I then relate some descriptive information about the NGSS and these standards' relative changes from previous versions. To help the reader understand the importance of the research questions, I share current literature on using science kits in elementary classrooms and a brief history. I describe the components of science instructional materials and then research on using kit materials for science instruction in elementary classrooms.

Chapter three outlines the study's methodological approach, a mixed methods design consisting of a survey of a pool of teachers and one-on-one interviews. The survey revealed patterns and trends in teacher interactions with instructional materials broadly. The interviews shed light on specific teachers' planning and enactment of science instruction and the use of materials. The NSSME+ assumes no position on what type of instructional materials best teach elementary science. The survey and interviews in this study only include teachers who use science kits developed by the Smithsonian Science Center and marketed as *Smithsonian Science for the Classroom* (also known as SSEC). The sampling frame was composed from the list of districts that purchased *Smithsonian Science for the Classroom* materials from Carolina

Biological Supply Company. An explanation of the sampling plan appears in chapter three. The rationale for sampling procedures is also included.

Chapter four presents data collection and analysis procedures. This chapter includes demographic information about survey respondents and interviewees and sample instructional materials collected from interviewees. Findings in this chapter appear according to the research question to which they best apply as opposed to the order of data collection.

Chapter five contains a summary of the findings of the study. The chapter also includes a description of the study's limitations and suggestions for further research. Implications of the study for teachers, administrators, professional development providers, and curriculum materials developers are also noted. A summary of the salient points of the study concludes the chapter.

Summary

While efforts to reform science education to create scientifically literate citizens and keep our country competitive in the global markets have been implemented since the late 19th century, the results of these efforts appear dubious at best. Numerous attempts at the national level to ensure a rigorous and equitable science education for all students have resulted mainly in very little change. America still lags behind other countries in international tests. Our nation's report card reveals that science proficiency at the elementary level has decreased or remained stagnant over the last decade. The newest attempt to correct this is the NGSS, first released in 2013 and adopted, as written or adapted, in 44 states and the District of Columbia. These standards require a shift in teaching science and therefore how students learn science. Instructional materials exist to help with the heavy lifting of the NGSS, and an increasing number of districts across America are now using kit-style materials in elementary classrooms. Understanding how these materials are used at the classroom level is vital. This knowledge can inform stakeholders and give students the foundational science instruction required to prepare a citizenry to face future challenges.

Chapter Two: Literature Review

Since the late nineteenth century, educators have argued that meaningful science learning occurs when students construct knowledge by experiencing and investigating physical and natural phenomena (DeBoer, 2014). Despite efforts by educators since Dewey's time, we have yet to achieve that goal. The current science reform effort is based on *The Framework for K-12 Science Education* (hereafter known as the Framework), which builds on this historical argument by leveraging research as well. The Next Generation Science Standards (NGSS), developed from the Framework, subscribe to the principles set forth more than a century ago. Additionally, the vision of science instruction laid out by the Framework stresses that equitable, high-quality science education needs to be accessible to all kindergarten through twelfth-grade students.

Education research over the last twenty years shows that young children are much more capable of scientific reasoning and understanding than once thought (Kang, 2018; Windschitl & Barton, 2016; NRC, 2012). For example, at an early age, students can reason far beyond just describing their observations and develop a beginning understanding of concepts once thought too complicated for them (Duschl et al., 2008; Windschitl & Barton, 2016). Studies have also contributed to a more robust view of science than the previous linear "scientific method" idea of how scientists conduct their work. This more contemporary view conceptualizes science as a range of practices such as constructing evidence-based explanations, model-based reasoning, and emphasizing the interrelationships between scientific practices, concepts, and ideas. (Roth, 2014; Bismack, Arias, Davis & Palincsar, 2014).

The Next Generation Science Standards released in 2013 and adopted or adapted by most states in the US reflect this new view of science and raise the bar for how students learn science in classrooms across the country, presenting a significant shift in both teaching and learning in the classroom. However, now that we know what students are capable of, “we can see the gap between the current expectations for learning and how science is taught in the classroom” (Windschitl et al., 2016, p.1102).

Change in education moves slowly for many reasons (Smith, 2020). New initiatives often take several years to implement, and many states have taken a multi-year approach to the NGSS. The paradigm shifts in teaching and learning required by these standards are substantial. Teachers need to move away from traditional activities such as having students memorize facts and vocabulary and move toward activities that engage students in sensemaking, facilitate modeling, and allow students to participate in argumentation and explanation building (Kang, 2019; Lee et al., 2019).

While research specific to NGSS-aligned teaching and learning is just beginning to emerge, evidence exists from previous efforts that instructional materials play an essential role in any process of education reform (Davis et al., 2016; DeBarger et al., 2017). Therefore, it is likely that instructional materials used in the classroom will contribute to the success or failure of reaching the vision of the NGSS. Understanding the use of instructional materials during science instruction, an area of education that needs more research (NRC, 2007), can assist in successfully implementing the NGSS, giving students nationwide access to high-quality science instruction. This chapter will review the literature regarding the current state of elementary science instruction, the role of instructional materials in science instruction, and teacher enactment of instructional materials in the era of the NGSS.

Current Trends in Elementary Science Instruction

Understanding instructional materials used in the classroom is essential to successfully implementing the NGSS. There is overwhelming evidence, however, that teachers face obstacles that could impede the shifts in instruction required to implement the NGSS successfully. Based on the 2012 NSSME+, Trygstad et al. (2013) described science instruction as "noticeably inadequate," a sentiment echoed by Smith in a review of the NSSME+ administered six years later in 2018, despite the adoption of the NGSS by many states beginning in 2013 (Smith, 2020).

Research in science education has consistently shown that most elementary teachers are generalists, teaching all subjects to their students, but feel most unprepared to teach science (Roth, 2014; Appleton, 2003; Dorph et al., 2011; Banilower, 2011; Milner et al., 2012). The 2018 NSSME+ confirm that only about 31% of science teachers reported feeling very prepared to teach science compared to 77% of teachers who felt very prepared to teach ELA and 73% who felt very prepared to teach mathematics. These statistics are not surprising. Preschool and elementary teachers tend not to have degrees, extensive coursework, or certifications in science or engineering due to the nature of elementary certification in most states (Banilower et al., 2018; Doan & Lucero, 2021; Plumley, 2019). The 2018 NSSME+ showed that 89% of elementary teachers had some college coursework in life science and less in chemistry. However, only one percent have engineering coursework, an area of heavy emphasis in the NGSS (Smith, 2020).

It is essential to note that in the 2018 NSSME+, over 90% of teachers believed that:

(1) Teachers should ask students to support their conclusions about a science concept with evidence.

(2) Students learn best when instruction is connected to their everyday lives.

(3) Students should learn science by doing science, and

(4) Most class periods should allow students to apply scientific ideas to real-world contexts (NSSME+, 2018, p.15).

These findings support a positive belief system for teaching and learning science that can be built upon, as teachers often lack the knowledge necessary to provide these experiences in the classroom (Thomson & Gregory, 2013). This dichotomy between beliefs and what is taught in the classroom can severely impact the implementation of standards-based instruction. Further, professional learning opportunities are not yet sufficient to meet the needs of teachers tasked with implementing such ambitious standards (Banilower et al., 2013; Smith, 2020).

According to the 2018 NSSME+, teachers report a lack of time to teach science. A trend across the US shows that the number of minutes designated to science instruction in elementary schools is significantly less than in other disciplines, most notably English Language Arts and mathematics, disciplines associated with high-stakes testing. Teachers across the US reported a daily average of 87 minutes spent on English Language Arts instruction, 58 minutes on mathematics instruction, and only 20 minutes per day on science instruction. Further, statistics from the 2018 NSSME+ show that most students do not receive science instruction more than twice a week. High anxiety levels and high stakes testing demands in other content areas create an atmosphere where science instruction becomes expendable (Dickerson et al., 2006).

Instructional materials are essential in classroom instruction and, as noted earlier, in any reform effort. The 2018 NSSME+ reported that teachers use various instructional materials in instruction (to be reviewed later in this section). Perhaps most troubling is that half of teachers reported that the materials used for science instruction were published before 2009, well before the NGSS were released. Expecting teachers to adapt materials to align with new standards is both unrealistic and unfair given the other classroom responsibilities and lack of opportunity for them to develop their curriculum writing knowledge.

While not new problems in elementary science, the lack of time, content and pedagogical knowledge, and quality instructional materials complicate the reform efforts of the NGSS, which require a significant change in teacher practice (Lee et al., 2014. The shifts involve abandoning traditional approaches that emphasize correct answers, memorized procedures, and the role of the teacher as the possessor of knowledge to students participating as agents in knowledge construction (Miller et al., 2018; Zangori & Pinnow, 2020). The standards promote student participation in scientific and engineering practices and engagement in sense-making, both of which require time, adequate teacher knowledge, and high-quality materials.

Instructional Materials

The curriculum has long been considered crucial to implementing reforms (Stein & Kim, 2011). Sherin and Drake (2009) describe curriculum as "an avenue for changing teacher practice, as long as the teachers learn to trust the coherence presented by the materials" (p.7). To address the changes espoused by the research, many publishers have produced instructional materials that align with the vision of the NGSS. In some cases, these materials also provide teachers with guidance in pedagogy for instructing students to meet the standards (Davis et al., 2016).

For decades, the National Science Foundation has been funding the development of instructional materials based on educational research (Taylor et al., 2007). The recommendations from the research include addressing students' prior knowledge, connecting new knowledge to big ideas, and helping students take control of their learning (NRC, 2001). Given the vital role of instructional materials, it is crucial to understand how teachers use them in the classroom. While it is beyond the scope of this study to investigate the effects of implementation on student learning, it seems evident that the goal of any instructional material is to optimize student learning. However, before that can be accomplished, more research is needed to understand how teachers implement instructional materials during the planning and enactment of science lessons (Davis et al., 2016; McFadden, 2019).

Definition of Curriculum and Instructional Materials

The term *curriculum* has varied educational definitions. Some definitions focus on content, some on learning experiences, behavioral objectives, or plans for instruction (Lunenburg, 2011). This study relies heavily on the definitions found in two sources, the Framework (NRC, 2011) and research conducted in mathematics by Janine Remillard and Daniel Heck. According to the Framework, "Curriculum refers to the knowledge and practices in teachers' subject matter areas that teachers teach and students are supposed to learn" (p. 246). Remillard and Heck (2014) define curriculum as the "plan for experiences that learners will encounter as well as the experiences they do encounter" (p. 707). They delineate curriculum into different categories, "each guided by particular entities in the education field and each with distinct components. For example, the *official* curriculum, authorized at the state level, consists of the curricular aims and objectives, the content of the consequential assessments, and the *designated* curriculum" (p. 708). For example, in New York State, the official curriculum is based on the Framework and, in the case of elementary science, is nearly identical to the NGSS. The *designated* curriculum refers to plans authorized by local educational administrations. In some states, district boards adopt specific materials or programs to become the designated curriculum for instruction. In other states, the decision about materials for instruction is determined at the state level. Describing math materials, Remillard and Heck note: "In many school districts in the US, the designated curriculum consists of a host of assembled packages of materials, instructional resources, and structuring guidelines designed to shape the content, pacing, and often the processes and tools of mathematics instruction" (2014, p. 710). This study draws its definition of instructional materials in science from the definition Remillard and Heck proposed for the mathematics-designated curriculum definition: assembled packages of materials, which may be commercial or teacher-developed instructional resources, and structured guidelines used by teachers and students during science instruction. These materials can include a teacher guide, student textbooks, physical materials used during investigations, and perhaps media content. This study uses the terms *instructional materials* and *curriculum materials* interchangeably.

Features of Instructional Materials in Science Instruction

The importance of instructional materials in instruction cannot be underestimated. Instructional materials can shape classroom activity (Ball & Cohen, 1996), influence teachers' pedagogical design capacity (Brown, 2011). Understanding how teachers use instructional materials in the classroom to enact NGSS-aligned instruction is directly related to the success of the reform effort that the NGSS promote (Smith, 2020).

Most instructional materials provide a scope, sequence, and step-by-step instructions and teacher background information for each lesson. Some curriculum developers create teacher materials that include guidance to enhance teacher learning about inquiry-based practices (Schneider, 2012). These materials, called *educative instructional materials*, are a portion of the teaching manual that assists teachers in understanding teaching reflective of the intentions of reform efforts. Educative materials "move beyond guiding teachers in completing lessons with their students to offer specific help for teachers to make the most of these opportunities to learn about teaching science" (Schneider, 2012, p. 324).

Educative materials can increase pedagogical content knowledge, help teachers understand the standards addressed, and alert teachers to possible student misconceptions of science ideas. For example, studies by Davis et al. (2016) found evidence of teacher use of educative features in student notebook entries. Specifically, they showed a greater uptake of science ideas and practices by teachers and students. In an era of reform, where an attempt to change the nature and scope of what is taught along with the methodology for doing so is desired, educative materials can be significant in teachers' learning of new ways of thinking and teaching (Ball & Cohen, 1996; Schneider, 2012; Davis et al., 2016; Remillard, 2000). Considering the new standards, educative instructional materials

> present a promising mechanism for supporting teachers in learning new instructional practices that will allow them to engage students in developing useable knowledge: students explaining phenomena, figuring things out, or finding solutions to problems utilizing scientific and engineering practices, scientific ideas, and crosscutting concepts (Krajcik & Delen, 2017, p. 1).

When these educative features appear in the teacher manual, teachers feel prepared, and students learn. However, these features are not helpful if teachers do not use them. Evidence suggests that more needs to be understood about how teachers use these educative features to inform their instruction.

Science Modules (Science Kits)

The focus of science reform efforts of the 1960s leaned heavily toward inquiry, encouraging instruction where students engage directly with hands-on instructional materials. One way to address that goal was to develop science kits, where teacher and student materials required to complete a series of hands-on investigations are assembled as a unit. Panels of scientists, psychologists, teachers, and evaluators created early versions of science kits promoted by the federal government and funded by agencies such as the National Science Foundation (Jones et al., 2012). Eventually, funding for developing these kits dried up, making the effort difficult to sustain (Shymansky, 1989). Later reform efforts called for improved science literacy and inspired the development of materials and better teacher preparation to reach that goal, driven by advances in cognitive science (Young & Lee, 2005).

The last few decades have seen many commercially produced kits available for purchase. These materials, marketed as being aligned with national reform efforts, often have similar component features from unit to unit and from grade level to grade level, allowing users to anticipate the pace, format, and essential materials provided for the lessons in each unit (Jones et al., 2012). "Many of these kits provide materials and teacher guidance to allow children to construct science knowledge and develop science process skills by working on particular science topics in-depth" (Young & Lee, 2005, p. 472). They include appropriate sequencing of science concepts and have undergone field testing by curriculum developers (Dickerson et al., 2006). While textbooks are still the primary instructional material used in classrooms, the number of teachers using kit materials is rising, especially in elementary classrooms (NSSME+, 2018).

While some studies suggest that using science kits can have positive outcomes for students and teachers, other studies question the effectiveness of such kits. For example, studies suggest that instruction using kit materials results in positive student learning outcomes. Shymansky et al. (1990) suggest that teaching from science kits provides more positive student outcomes and, in some cases, student attitudes toward science. A study by Houston et al. (2008) found that using science kits for instruction created a positive learning environment in terms of students' satisfaction and cohesiveness compared to traditional textbook-only use for instruction (Houston et al., 2008; Jones et al., 2012). A positive learning environment leads to better student attention and participation in class, integral components of learning. Other arguments for the merits of science kits include that students who generally feel disenfranchised may feel more empowered and engaged in lessons deployed from kits (Houston et al., 2008).

In contrast, some research suggests that instruction using science kits may not necessarily result in more positive student outcomes when compared with traditional teaching via textbooks (Dickerson et al., 2006). Other research shows that the materials in the kits themselves do not lead to automatic positive outcomes but rely heavily on the extent of professional development of the teachers using them. In one study, Young and Lee (2005) suggested that high-quality materials kits are desirable but must be combined with substantial teacher professional development to affect children's learning of science positively, implying that it is how the teachers use the materials for instruction that allows for student learning, aligning with Remillard's conception that materials are only as effective as their implementation. There is also a question of how reliable the evaluations of the kits are. Houston et al. (2008) note that "Evaluation of instruction with kits often relies heavily on academic achievement tests, which do not give a complete picture of classroom instruction" (p. 35).

Science kits contain materials that help students explore big ideas through hands-on investigations, but many commercial kits also contain educative materials for teachers. As stated earlier in this chapter, these features help teachers increase their pedagogical and content knowledge when employed. Rice and Roychoudhury (2003) found that using science kits helped teachers feel more confident teaching science. Dickerson et al. also note, "If teachers exhibit greater confidence in their science teaching by using kits, it is logical to conclude that a systemic implementation of kits in a school district would make a difference for teachers who dislike science or who lack confidence in teaching science" (2006, p. 48). Some studies suggest that teachers who use kit materials in instruction reported a "significantly greater frequency of utilizing exploratory activities, including open-ended questions and asking students to supply evidence explaining concepts" (Houston et al., 2008, p. 470).

It is difficult to determine if years of teaching make a substantial difference in using kits in elementary classrooms. A study by Jones et al. (2012) was anticipated to show that teachers with fewer years of teaching experience would have some familiarity with science kits in their teacher education programs and, therefore, tend to use kits more than teachers who had more years of experience. Results showed the opposite to be true. Teachers new to the field prioritized other issues, such as classroom management and curriculum planning, and therefore relied on more traditional teaching methods. While some teachers with more years of experience did opt for traditional teaching methods over the newer innovations, perhaps because of being set in established routines, many teachers in this category did use the kits more often than their newer counterparts.

Science kits present an opportunity to create an "all-inclusive" packaged program meant to provide coherence to instruction for students and, at times, include educative materials that benefit teachers. However, conflicting evidence on the effectiveness of using kits for instruction suggests that studies directly related to using kits to teach the NGSS, from both student outcomes and teacher use perspectives, are warranted.

Teacher Enactment

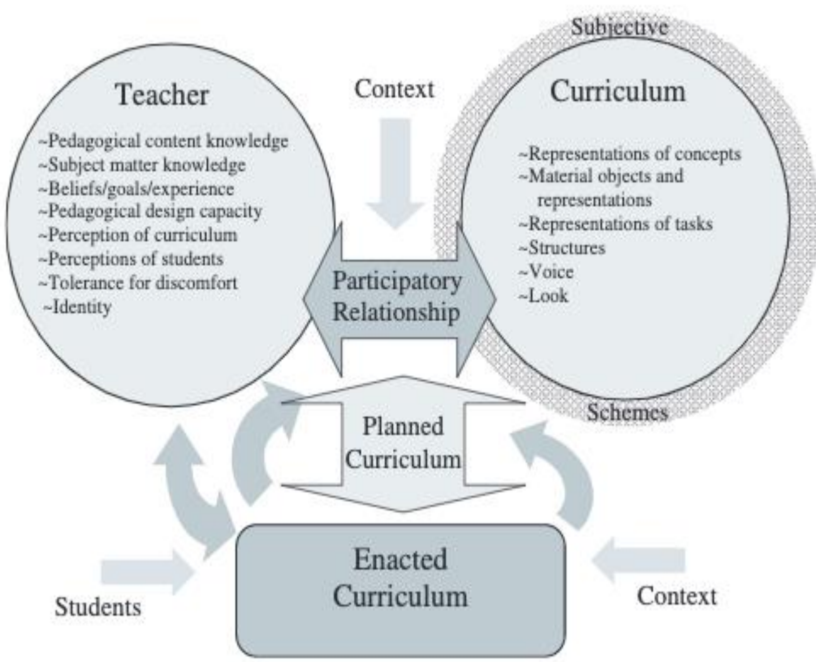
Brown (2009) points out that the role of instructional materials is much like the role of sheet music, intended to "convey rich ideas and dynamic practices, but they do so through succinct shorthand that relies heavily on interpretation" (Brown, 2009, p. 21). To continue the comparison, Brown suggests that both are inert objects and only come to life through the use and interpretation of a practitioner. Remillard (2018) suggests that lesson enactments, like performing music, are different in style, pace, emphasis, or quality. The quality of instruction is "related to the teacher's ability to interpret, make decisions about, and leverage the resources as she designs and enacts instruction" (p. 484).

This study draws the definition of the term *enactment* from Remillard's (2005) definition of *curriculum use* in mathematics: teachers interact with, draw on, or refer to and are influenced by materials and resources designed to guide instruction, implying that an interaction occurs. Once in the hands of teachers, instructional materials move from being part of the designated curriculum, a set of materials and instructions for how to use them, toward the actual classroom enactment and, therefore, are *operational,* a curriculum category that includes the transformations that occur during enactment (Remillard & Heck, 2014).Therefore, this study defines *enactment* as the interaction of teachers and the materials drawn upon during planning and delivering science instruction.

As teachers design instruction for their science classrooms, they interact with instructional materials in complex ways. What the interactions look like and how they occur is of enormous consequence to student learning (Windschitl & Barton, 2017). Remillard (2005) refers to the relationship between teachers and instructional materials as a *participatory relationship*, meaning that teachers have beliefs, perspectives, and pedagogical and content knowledge that influence how they view, plan with, and enact the materials and the materials have characteristics that influence how teachers use them in that planning and enactment. The interaction between teacher and curriculum is shaped by what each brings to the relationship, which in turn helps shape the planned curriculum's design, which becomes the basis for the enacted curriculum. (See Figure 2.1)

Figure 2.1

Components of Teacher-Curriculum Participatory Relationship



Note: Remillard, 2005

In Remillard's (2005) review of the mathematics education literature, she identified four conceptions of curriculum use. These include the idea that teachers *follow or subvert* instructional materials, *draw on*, interpret, or *participate with* instructional materials. Following or subverting the instructional materials is related to implementing the instructional materials with fidelity. Drawing on, interpreting, and participating with instructional materials relates more closely with teachers incorporating their beliefs and perspectives as they make meaning of the materials and how to use them. Brown's (2009) work with science teachers coincides with Remillard's work with mathematics teachers. Brown proposes that some teachers *offload* decisions to the curriculum, meaning teachers follow the curriculum with fidelity and follow recommendations and directions in the materials, corresponding to Remilllard's *follow or subvert* concept. Other teachers, according to Brown (2009), may *improvise*, using little of the instructional materials guidance or *adapt* instructional materials, a concept like Remillard's concept of interpreting or participating with instructional materials, where teachers make changes to the instructional materials based on context or perspectives.

Brown (2009) characterized teachers' curriculum enactment as offloading, adapting, or improvising: he referred to the teacher's ability to make productive decisions about what and how to enact instructional materials as *pedagogical design capacity*. "Each way of enacting instructional materials involves teachers making decisions based on their beliefs, goals, pedagogical content knowledge, subject matter knowledge, and knowledge of their students and the instructional materials. Teachers use their pedagogical design capacity to "perceive and mobilize 'instructional materials in the form of enactment" (p. 29).

Although multiple sources cite the need for more research on how teachers use instructional materials (Davis et al., 2016; Dickerson et al.; Charlambous et al., 2012), several themes permeate the instructional materials landscape. For instance, drawn from mathematics research, Davis et al. (2016) found that these themes also held in science classrooms:

1) In practice, teachers tend to alter the materials and reduce the cognitive demands of tasks.

2) Teachers tend to modify the materials to align with their current beliefs and practices rather than the reforms espoused by the instructional materials.

3) Teachers vary tremendously in how they enact lessons.

Theme # 1: In practice, teachers tend to alter the materials and reduce the cognitive demand of tasks.

While there is high variability in how teachers interact with instructional materials and in the enactment of reform-oriented instructional materials, teachers commonly made changes to the cognitive demand of tasks embedded in instructional materials. "In science, this often eliminates some of the more challenging or ambitious science practices" (Kang, 2019, p. 22).

Theme #2: Teachers tend to modify the materials to align with their current beliefs and practice rather than the reforms espoused by the instructional materials.

When science instruction occurs with hands-on materials, research suggests that it often differs from the high-quality instruction promoted by research. Often, it is an activity for its own sake with little or no intellectual engagement by the students with essential ideas or connection to science ideas (Weiss et al., 2003; Banilower et al., 2006). Appleton (2003) also noted that when teachers teach hands-on science, they often borrow activities and strategies from other content areas and their own experiences, which may or may not align with quality science instruction.

Educators have argued that meaningful science learning occurs when students construct knowledge by experiencing and investigating physical and natural phenomena in the world. This vision is consistent with current science education reforms (Lead States, 2013) and the learning sciences (Russ & Berland, 2019). The focus on letting students figure things out is also a goal many classroom teachers express. In the case of the NGSS, figuring things out means allowing the students to engage in science and engineering practices to construct explanations. However, students' explanations in elementary grades are often incomplete or incorrect. Numerous researchers argue that this may indicate that this is a step in sensemaking and that an acceptable explanation will come with time (Windschitl & Calabrese, 2016; Russ & Berland, 2019). While these naive science explanatory models serve as essential resources for early learners to build upon, when students articulate these ideas, it can create challenges for the teacher as their students' answers may appear faulty, off-topic, or unconnected to the content in an easily discernible way (Reinsvold & Cochran, 2012; Zangori & Pinnow, 2020). When faced with a student's incorrect or incomplete explanation, teachers tend to fall back on the traditional priority of instruction and lead students toward the correct answer (Russ & Berland, 2019).

Theme #3: Teachers vary tremendously in how they enact lessons.

Research suggests that teachers bring their perspectives about teaching science and instructional materials to the teacher-instructional materials relationship and that teacher enactment of instructional materials is dependent on a host of factors such as individual beliefs, familiarity with the goals of the materials, the extent of pedagogical and content knowledge, knowledge of students, time constraints, and district and state policies. (Remillard (2005; Brown, 2011). Further, teachers use various materials that are diverse in quality, alignment with the NGSS, and development. For instance, some teachers use materials they have developed alone or with colleagues, some use a textbook as the primary resource, and others use kit materials. Variations such as these make it difficult to prescribe a "one size fits all" solution to the impediments of enacting the NGSS. Because of the individual experiences of teachers, many researchers claim that it is impossible for teachers to implement units with complete fidelity.

The climate of high-stakes testing, policies that favor math and ELA instruction, and low priority for science instruction make it difficult for teachers to fit science instruction into their schedules (Johnson & Dabney, 2018; Judson, 2013). For example, teachers widely report a lack of time to complete the lessons as directed in the instructional materials, forcing them to choose lessons or portions of lessons that fit into the time allotted for science instruction (NSSME+, 2018).

It is difficult to know if enough time has passed to see the impact of the NGSS, especially in light of the disruption presented by the COVID-19 pandemic. However, the findings above suggest that the alignment of materials to new standards may present challenges for some classroom teachers. They may skip or adapt materials or use a "pick and choose" approach due to personal perspectives about the standards, materials, or teaching science in general or the time constraints many teachers face. This approach could make the materials less coherent. Despite the vision of the NGSS and its adoption in some states as early as 2013, only one in four elementary teachers reported on the 2018 NSSME+ that they heavily emphasize students learning how science is conducted and put even less emphasis on engineering. Further, two-thirds to three-fourths of science teachers agreed that students should be given vocabulary word definitions at the beginning of a science lesson and that hands-on activities should reinforce concepts in science that students have already learned (Smith, 2020). These ideas relate more closely with traditional teaching models than the NGSS, and it is difficult to know what, if any, role the lack of access to NGSS-aligned instructional materials has on these practices.

We must recall that pre-NCLB legislation, researchers reported a recognizable story of science often being avoided by elementary teachers due to a lack of familiarity with the content and teachers having negative attitudes and feelings of inadequacy related to science (Tilgner, 1990). While research indicates that NCLB impacted science instructional time, we must also consider that when NCLB was enacted, many teachers were quite willing to draw attention to other subjects that they felt more confident to teach (Judson, 2013). We must be cognizant that with the move away from traditional teaching methods and the rigor of the NGSS, teachers may harbor feelings of inadequacy related to science, just as they did thirty years ago.

Enactment and Professional Development

While not the focus of this study, it is essential to mention examples of how teacher enactment of NGSS and the accompanying resources could be improved. After all, meeting the users' needs would raise the likelihood of implementing the standards and the vision of the NGSS.

Professional development may allow teachers to improve their enactment of the NGSS and use the resources more effectively. Evidence from the 2018 NSSME+ shows that teachers have received more professional development in science than reported in the 2012 NSSME+. However, the number of hours and frequency of professional development opportunities differ from the support required for such an ambitious shift in instruction. For example, in a study of how teachers addressed the scientific practices of the NGSS, designed to help shape a professional development program for second-grade teachers based on the NGSS practices, Kang (2018) found that when teachers were unsure of how to apply one of the practices in their science instruction, they chose to engage the students in that practice either minimally or not at all, concluding that teachers did not have sufficient background knowledge to address these practices confidently. However, a second study published in 2019, after teachers had received a year-long professional development program, showed a marked difference. Teachers in the second study reported that once sustained professional development was provided, they felt more confident and knowledgeable to engage students in the practices they had previously excluded.

Summary

Difficulties exist in finding time for science instruction in this era of high-stakes testing. As generalists tasked with teaching all subjects, elementary teachers often lack extensive science content knowledge. They, therefore, lack confidence in their ability to teach science. The robust shift in pedagogy and content prescribed by the NGSS requires teachers to take on new ways of thinking about teaching and learning science in their classrooms. After nearly a decade, there is still a ways to go to meet the vision of the NGSS for all students. While general information regarding science teaching in elementary classrooms is well documented in the literature, more needs to be known about the classroom-level use of instructional materials during science planning and enactment. Studying classroom-level use of instructional materials will help us understand how to support teachers in providing instruction more in line with the vision of the current standards.

Chapter 3: Methodology

Rationale for Study

Literature on science teaching supports the participatory relationship between teachers and the instructional materials used for instruction. Remillard and Heck (2014) note that teacher enactment of curriculum and instructional materials are mutually influential. Instructional materials adopted in classrooms to deliver the official curriculum designated by state or national standards supply teachers with vehicles to enact that curriculum. This enactment phase influences student outcomes. An increasing volume of literature exists about instructional materials available to teachers and how instructional materials can influence learning (Ball & Cohen, 1996; Arias et al., 2016; Davis et al., 2016). What is lesser known is how these materials are used during the planning and enactment of science lessons in the actual classroom (Remillard & Heck, 2014). This study aims to understand what teachers report about their use of kit-based instructional materials aligned to the NGSS. It asks:

1) How do teachers report using instructional materials in elementary science during the planning and delivery of instruction?
2) What modifications, if any, do teachers report making to elementary science instructional materials?
3) What rationales do teachers report for these modifications?

Teachers across America widely report district emphasis on instruction in English Language Arts and mathematics, leaving less time for science and social studies instruction (Trygstad et al., 2013; Banilower et al., 2013; Banilower et al., 2018; Davis et al., 2016). These time constraints and other mandates from state and local leaders can lead teachers to make decisions about the use of instructional materials that may ultimately create lessons with less cognitive demand and diminished opportunities for learning than intended by the materials developers. For example, due to time constraints, teachers may substitute a teacher-made vocabulary worksheet for a hands-on lesson where students participate in an investigation where the experience leads them to create their own definition of a key concept. According to Bloom's Taxonomy, a well-known classification system of learning objectives based on complexity, creating a definition from understanding requires more cognitive demand than filling out a worksheet (Hess et al., 2009). Research also supports the idea that elementary teachers are generalists and often do not have the background in science needed to be confident and comfortable with science content, leading them to skip or modify materials that they do not understand (Kang, 2018; Kang et al., 2019). Conversely, teachers may change materials to make lessons more accessible to their students and thus improve learning opportunities. For example, teachers may introduce more extensive notebook writing or board work into lessons or assimilate science reading and writing into other disciplines, thus providing more time for science and practice for reading and writing skills.

My personal experience as an elementary science coach in a local school district allowed a first-hand look at how difficult it is for teachers to "fit everything in," and nowhere was it more evident than when it came to science teaching. Assisting teachers as a science coach revealed to me that teacher decisions about science instruction in general and use of hands-on materials varied widely, and access to commercial module materials necessary for students to complete the unit, did not necessarily mean that teachers employed them in the manner seemingly laid out by kit developers or professional development providers. More exploration and explanation seemed essential, and it is the aim of this study to address that need. This chapter will explain the methodological approach to this study, sampling method, implementation, data collection and analysis.

Methodological Approach

I begin this section with an overview of the methods employed in the design of this study which consisted of a survey and interviews. I provide a rationale for the methodological approach, a description of the research design, as well as an explanation of the sampling method and coding decisions.

Mixed Methods Rationale

Because the research undertaken by this study included uncovering patterns and trends in teacher practice in both a general and specific sense, and understanding the rationale behind the decisions to change, skip, or add to instructional materials, a mixed-methods approach was appropriate. In this approach, the investigator "integrates the two [methods] and then draws interpretations based on the combined strengths of both sets of data to understand the research problems" (Creswell, 2015, p.2). The appeal of mixed methods research lies in the ability to combine both 'numbers and a story' (Spalter-Roth, 2000) to generate new knowledge. "The combination of both general numeric findings and specific cases exemplifying those findings generate a synergy that neither can alone" (Teddlie & Sammons, 2010, p. 116).

Certain types of information can be gleaned from responses to survey questions. For example, responses from the survey in this study shed light on teachers' general practices regarding the use of the SSEC materials and reflected the general responses from teachers who participated in the NSSME+. However, the interview captured the nuances of teaching a particular classroom of students. The interview allowed respondents to add explanations and details about their interactions with the materials, giving a more vivid picture of their practice.

Research Design

This research study consisted of two phases, a survey in phase one, followed by semi-structured interviews in phase two. The use of an online survey allowed an opportunity to gather data from participants in a short time frame and allowed access to teachers from across the country (Braun et al, 2020). I did, in fact, receive responses from teachers in ten states and from rural, suburban, and urban schools.

Phase two of the study consisted of one-on-one semi-structured, recorded, and transcribed phone interviews with 12 of the survey respondents. While the survey information was helpful, it was more generalized information. Interviews allowed the participants to provide context and expand on their survey responses, provide comments beyond the survey questions, and ask questions (Creswell & Guetterman, 2019).

The nature of this study required an analysis of the survey responses before interviewing respondents as the interview questions were derived from those responses. As a result, a sequential exploratory design was appropriate in this mixed methods study. In this type of design, the researcher collects quantitative data first, and analysis of this data informs the subsequent collection of the qualitative information and the development of a new tool used to collect qualitative data (Merriam & Tisdell, 2016). In general, the qualitative data explains the findings in the quantitative data (Creswell, 2015). The qualitative data responses to questions specific to SSEC instructional materials prompted the development of questions about teacher practices that I wanted to interrogate in the interview phase to address my research questions.

Sampling

The purpose of this study was not to quantify or generalize the findings, but to gain understanding of the practices of a particular group of teachers; those that use the SSEC materials in instruction. Therefore, a purposeful sample selection process was employed to recruit participants for this study. In a purposeful sample selection, participants are recruited based on their knowledge of the phenomena under study (Merriam & Tisdell, 2016: Creswell, 2016). Purposeful sampling assumes that the researcher places emphasis on in-depth understanding of specific cases which are information rich: those from which the most can be learned about the central focus of the study (Patton, 2015). When the purposeful sample selection is criterion-based, participants are chosen attributes central the study. The criteria for participants in this study included:

- Teachers who taught the SSEC units in a district where the SSEC instructional materials were adopted district-wide, K-5.
- Teachers who taught fourth or fifth grade or shared staff who taught fourth or fifth graders or both such as STEM or science lab instructors.
- Teachers who meet the above criteria and whose grade level and email information appear on a school or district website available to the public.

Carolina Biological Supply Company shared sales information regarding the SSEC materials for the past ten years. However, sales from 2014 to the present were most important for this study because those sales would coincide with units produced to align with the Next Generation Science Standards. The sales data provided included the names of districts and educational services agencies, the state where they reside, and the total amount spent on complete kits and refills to replace consumable items. The number of kits purchased by individual districts was not included in the data. However, the population of interest was teachers whose districts have district-wide adoption of the *Smithsonian Science for the Classroom*. To this end, the first step was to arrange the data by the amount spent on kits and refurbishment materials. This data ranged from districts and educational service agencies that spent several million dollars to those that spent less than one hundred dollars.

Several factors influenced the estimate of how much a district would spend to implement the kits in kindergarten through fifth grade. There are four Smithsonian science units for each grade level per year and estimating each building to have three classrooms per grade level for grades K through five, a rough idea of the cost of kits per building could be determined. Based on current pricing from the Carolina Biological Supply Company website, each kit costs approximately $700-$1100. If a district has three classrooms per grade level, it will spend approximately $8000 per grade level to implement the kits in its elementary schools fully. A district would need to spend nearly $50,000 per building if it was using the *Smithsonian Science for the Classroom* units district wide. Using this estimate, only districts listed in the data as purchasing at least $50,000 in *Smithsonian Science for the Classroom* materials were eligible for this study. Any district that spent less than $50,000 was eliminated from the sample frame, making the data more manageable and increasing the likelihood that the districts that remained on the list had fully implemented the Smithsonian materials.

In the next phase, the information on the district website determined whether a district remained on the sample list or was excluded. Most district websites listed their elementary schools and provided a link to access the individual elementary school websites. Most of the individual elementary building public websites listed a staff directory with teacher names, teaching assignments, and emails. If the teachers' grade levels or emails were unavailable on the district or school's public website, that school was eliminated from the list of prospective survey recipients.

Given the variation across the US in the amount of science instruction students receive, focusing on fourth and fifth-grade teachers made sense since most states require science assessment in either fourth or fifth grade. The emphasis on state testing and test preparation throughout the country meant that fourth and fifth-grade teachers would most likely prioritize teaching science. Therefore, fourth and fifth-grade teachers in districts that had fully adopted the SSEC materials became the target sample.

I located fourth and fifth-grade teachers through the individual elementary school or district websites. I created an Excel spreadsheet with state, district, school, teacher name, and grade level, along with their school email. In some cases, one teacher for science was listed for multiple grades. This inferred that science was part of the specials rotation in those districts. Since science instruction appeared to be delivered outside the regular classroom in those instances, I entered the science teachers' names into the sample list instead of the fourth and fifth-grade regular classroom teachers. This spreadsheet served as the final sample set of survey recipients.

Phase One: Survey

For phase one of the study, I determined that to access teachers in my sample set with the time and resources available to me, an online survey method would be helpful to reach as many teachers in my sample from various regions and demographics as possible. Online surveys are a widely accepted method of study in the social sciences, and electronic surveys have become common as Internet access becomes widespread. Qualitative surveys offer one thing that is relatively unique within qualitative data collection methods – a 'wide-angle lens' on the topic of interest that provides the potential to capture a diversity of perspectives, experiences, or sense-making (Toerien & Wilkinson, 2004). I was interested in perspectives from teachers from regions across the country. A survey seemed a sensible solution. Survey recipients also provided me with a pool of possible interviewees for the second phase of my study.

I chose to survey and interview teachers who use the Smithsonian materials for the alignment of the materials with the NGSS, the focus of the units on investigating phenomena or solving problems, my familiarity with the materials, and the extensive review and revision process that developers employ before the units become available for purchase. I taught and field tested the *Smithsonian Science for the Classroom* materials in my capacity as both a science lab instructor and a science coach. Knowing the units well and working with colleagues to implement the lessons in their classrooms would allow me to interpret the survey results better and understand the interviewees' ideas. They would be able to speak to specific lessons and units that I would be familiar with, which would help make the most of the thirty minutes of interview time. In our conversations, I would better understand the specifics of the unit we were discussing.

The *Smithsonian Science for the Classroom* materials are created by curriculum developers from the Smithsonian Science Center. The materials are subject to review by practicing teachers and field-tested in multiple classrooms. Developers make revisions before the materials are published based on the feedback from the field. Further, the Smithsonian Science Center has submitted several of the units for consideration to receive the NGSS Design Badge, "a digital badge given to science units designed for the Next Generation Science Standards (NGSS) that have earned a rating of "E: Example of high-quality NGSS design" on the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for Science based on a review conducted by Achieve or its Science Peer Review Panel" (Achieve.org). Given the extensive development process, I am confident these materials align well with the current standards.

Focusing the study on one series allowed for identifying trends that emerged from edits to the same materials. If I had included multiple series in this study, variability in edits could have been due to product variability. Using one series, the variability in edits is more likely due to the teacher's decisions.

Survey Design

The survey for this study consisted of 26 questions adapted from the 2018 National Survey of Science and Mathematics Education (NSSME+), sections entitled *Elementary Science Instruction, Resources Available for Elementary School Science Instruction,* and *Factors Affecting Elementary School Science Instruction* distributed by Horizon Research, Inc. and funded by the National Science Foundation. This survey is administered every six years, provides data on mathematics and science education in the United States, and informs policy decisions and research regarding mathematics and science teaching (http://horizon-research.com/NSSME+/). The sections of the NSSME+ listed above contain questions regarding teacher experiences with planning and teaching science, professional development in science, using instructional materials in science, and attitudes and beliefs about science teaching and learning, areas of interest for this study. Adapting questions from the NSSME+ made sense because the questions from the NSSME+ had already been tested for validity and reliability, meaning that the constructs in the study measured what they meant to measure (Heckathorn, 2020). The questions on the NSSME+ were not specific to any published series or kits but were relevant to this study. Therefore, I altered the generic questions of the NSSME+ to be specific to the SSEC materials where appropriate. I borrowed other questions as written. Since the study focused on teacher use of instructional materials aligned with the NGSS, questions concerning how often teachers engaged their students in the scientific practices, how often and what types of materials teachers added to the kit materials, and rationales for changes made to the materials were included in the survey. (See Appendix A for survey questions.)

Qualtrics is an online analytic tool allowing users to create, distribute, collect, and analyze survey data. The electronic nature of the program made it possible for teachers to respond to the survey questions at a time convenient for them and submit their responses by pressing a button. An extensive data analysis component of the Qualtrics program allows the researcher to filter responses and merge data. This feature was helpful when conducting the initial analysis of the survey data. Qualtrics provides options for data presentation, such as in graph and numeric format, making it easy to see outliers and significant differences in responses upon initial analysis and note trends and areas of interest for more in-depth analysis (Qualitrics.com). Qualtrics also allows the researcher to include different types of question styles in the survey, including open and closed-ended questions, multiple-choice, short-answer, and Likert scale, allowing for the collection of various types of data. The ease of use for the researcher and survey respondents was critical in selecting the Qualtrics program.

The survey questions asked participants to provide school demographics and teacher characteristics such as the number of years teaching, ethnicity, and grade level. Questions included school demographics as well. Questions regarding their use of *Smithsonian Science for the Classroom* instructional materials focused on time for science instruction, use of unit materials, as written, changed, skipped or supplemented, as well as engagement with the scientific and engineering practices outlined in the NGSS and included in the teacher materials.

In addition to the 26 questions, the survey invited teachers to submit their email if they chose to be entered into a drawing for one of ten $10 electronic Amazon gift cards. A second invitation asked participants to leave contact information if they were willing to participate in a follow-up interview. Seventeen respondents provided an email address to contact for setting up the interview. Once anonymized, these teachers were entered into a random drawing for one of four $50 Amazon gift cards.

Survey Implementation

A total of 1,354 fourth and fifth-grade teachers received an email that included an introduction to the study, institution, and advisor information, an explanation of the purpose of the study, incentive options for completion, assurance of confidentiality, an electronic consent form, and a link to the survey. Surveys went to the emails in small batches by district to avoid being tagged as junk mail. See Appendix B for a list of the number of emails by state, districts and schools.The survey remained open for four weeks, with a reminder email sent in week three. At the end of the survey document, respondents were invited to voluntarily submit their email to enter into a drawing for one of ten $10 electronic Amazon cards. Twenty-nine respondents submitted an email for this purpose. All other respondents remained anonymous.

Survey Data Analysis

The Qualtrics computer program was used for initial data analysis. Because of the small number of respondents, I could not analyze the responses for statistical significance or generalizability. Therefore, all analysis was completed by organizing the data on Excel spreadsheets and using the Qualtrics tool for clustering similar data and transferring the data to Excel. I began by clustering data by grade level and then by familiarity with the SSEC modules (modules they had taught). To use some of the Qualtrics analysis components, I first had to change anecdotal information to numeric codes in some cases. For other attributes, such as when teachers picked a response that best described their practice, I could cluster like information as written. For example, I used the Qualtrics tool to cluster information about teachers' time teaching science and arranged the survey responses by categories. I then compared the number of minutes teachers reported with the number of minutes designated by the kit materials to determine if teachers were afforded the number of minutes required to teach an entire unit as written.

Although the number of responses was too low to determine statistical significance and generalizability, which was not the survey's goal in this study, the data analysis was necessary. I gleaned anecdotal information and noted that responses to the survey were generally aligned with the responses to similar questions in the NSSME+. For example, in the NSSME+ and this study survey, teachers noted lack of time as the main reason for skipping lesson material. Further, survey responses provided a pool of interviewees and raised questions and topics of interest that were explored more deeply during the interview phase.

Phase Two: Interviews

Phase two of the study consisted of one-on-one interviews by phone. I borrow the definition of research interview as any conversation between two people undertaken for the purpose of generating original data for research (Gubrium and Holstein, 2001). Interview types can range from highly structured, where the researcher asks the same questions in the same order to all participants or completely unstructured, or informal, where the researcher does not know much about the topic and the goal is to learn enough to formulate questions for further interviews (Merriam & Tisdell, 2016). Interviews are often used in qualitative and mixed methods research and is a popular method used by researchers to understand how people construct meaning around their personal experiences.

Interview Design

Several considerations were influential in the decision to conduct the interviews by phone. First, the geographical distance between the interviewees and I determined that most interviews could not occur face-to-face. As part of the protocol, I planned to remind participants of the protection of their privacy and the confidentiality of their responses. However, a phone interview added a level of anonymity that might encourage teachers to feel they could speak freely, especially if they wanted to divulge personal information about themselves as teachers or criticism that others, such as administrators, might not receive well.

The survey in this study provided information from teachers that was more specific than the NSSME+ because it focused on one specific set of instructional materials. However, it was not specific in capturing the experiences of individuals as classroom-level users of the SSEC materials. The purpose of the interview was to hear from those individuals.

Interview questions clarified trends in the survey results and gave more specific information about classroom teachers' strategies and the rationale behind their decisions about using instructional materials in their science instruction.

As noted earlier in the chapter, participants could submit their contact information if willing to participate in a follow-up interview. Interviews were semi-structured, an appropriate style for this study. In semi-structured interviews, I prepared a section of structured questions ahead of the interviews and asked questions that were not predetermined but were asked based on what teachers brought up during the interview. I also added questions when participants brought up an area of interest that I wanted to explore further, and therefore included questions about the topics in subsequent interviews. This format allowed me to respond to the situation as it unfolded (Merriam & Tisdell, 2015; Creswell, 2019). I prepared several questions ahead of the interviews, followed by open-ended questions that allowed interviewees to share their views, practices, and beliefs. I had a general plan of inquiry but also wanted respondents to share their unique and individual experiences. See Appendix C for a list of interview questions.

Interview Implementation

Interview questions were developed based on the study's focus and the survey data analysis. I conducted the interviews after I analyzed the survey data. While many interview questions were developed as themes arose during the survey analysis, I also included questions I anticipated and prepared beforehand. For example, questions about school and teacher demographics, SSEC units taught, years of experience with SSEC, and teaching time for science were asked of all interviewees. Since the interviewees also participated in the survey, I wanted to be sure they talked about time, preparation, and adding, deleting, or modifying materials or lesson directions, areas where survey responses aligned with the NSSME+ and the literature about instructional materials. I prepared questions about these topics specifically as backup questions if participants did not come to these topics on their own. When asked to "walk me through" unit planning and lesson planning, teachers presented individual experiences that prompted follow-up questions unique to their responses. The objective of the interview was to gain specific knowledge about individual teacher experiences with the SSEC instructional materials when planning and delivering instruction. Therefore, listening more and speaking less was desirable (Babbie, 2008).

I anticipated the interviews to be 30 minutes long. I began by reading the consent form explaining the use of the interview responses in the study and how participant privacy and confidentiality would be maintained by storing the transcripts of the interviews in a password protected folder on an SU server and that the interviewees would be referred to by pseudonyms in the dissertation. Once finished, I asked and received oral consent from the participant to be interviewed and recorded.

I requested an appointment to talk for 30 minutes to any survey participant who agreed to an interview by email. In the email, I offered dates and time frames and asked participants to send a phone number to call at the appointed time. I also carefully included times amenable to participants in different time zones. Participants made a choice that fit their schedule. A confirmation email was sent with a copy of the consent form once participants sent a return email. Five participants did not respond to my initial or follow-up emails, so they were removed from the participant list. I conducted the remaining twelve interviews within a two-week time frame.

I began the interview by asking teachers how their day was going and if the time to talk still worked. I continued by reading the consent form. Once I finished reading the form, I asked and received oral consent from the participants to be interviewed and recorded. Before I began recording, I asked participants not to mention specific location data about their district or school but only to respond to questions generally regarding demographics, such as whether the school was considered rural, urban, or suburban. Once I received oral confirmation that participants understood, I recorded the interview on a personal tablet. Once recorded, the conversations were transferred from the tablet to a password-protected SU account and deleted from the tablet. For privacy and confidentiality, each interviewee was referenced only by their first name and an assigned number in the recording. No other personal information was recorded. Recordings were sent to Rev.com for transcription and returned within 24 hours. The stored transcripts exist in a password-protected file on the SU server. They will be deleted once the Ph.D. process is complete.

Interview Data Analysis

The analysis of transcript data began by carefully reading the transcripts several times, making initial margin notes of first impressions, and highlighting areas that directly related to the research questions. I used action words to describe my thinking and got a general sense of the data collected. Some researchers refer to this initial analysis procedure as open coding (Merriam & Tisdell, 2016). After several interviews were complete and some shared ideas emerged, I began to use the NVivo program to code the data. NVivo is an online qualitative software program that allows the researcher to store, organize, analyze, and visualize data to identify trends and patterns. A more extensive explanation of how the NVivo program was used appears in the next section.

Coding

Inductive coding methods are widely accepted in qualitative research as this type of research promotes getting at the essence of how participants experience their world (Creswell, 2016, Merriam & Tisdell, 2016). In inductive coding, researchers develop codes directly from the data using phrases and words taken directly from study participants, thus staying very close to the data rather than prior ideas or understandings of the researcher (Linneberg & Korsgaard, 2019). To address any bias I may have, I chose an inductive method of coding to be sure that the codes came from study participants and that evidence from the study would support the findings.

During this course of the study, especially during the literature review phase, certain codes came to mind that I anticipated would likely be helpful when coding. However, I did not create an a priori codebook because I wanted to be sure to have concrete evidence that those ideas did, in fact, appear in the data. Qualitative analysis and coding are not the same, although coding is essential to analysis, but I felt that my ideas were too preliminary to be deemed codes I would definitely use to analyze the data I would eventually collect. I wanted to keep an open mind throughout the research process. "Even if the researcher is not involved in a formal analysis of the data at the initial stages of research, (s)he might be thinking how to make sense of them and what codes, categories or themes could be used to explain the phenomena" (Basit, 2005, p.145).

As mentioned above, I began coding the transcript material using an open coding system. I noted any ideas related to the research questions or purpose of the study in the margins. I looked for shared ideas from one transcript to another, adding new ideas as they developed throughout the process. This procedure created many ideas noted in the margins. At this juncture, I began using the data analysis program NVivo to organize the ideas.

Using an electronic means for coding saves the researcher time and provides a way to store and organize data (Creswell, 2016). I chose to use NVivo, a qualitative data analysis software program because it is "designed to aid in storing, analyzing, sorting, and representing or visualizing the data " (Creswell & Gutterman, 2019, p. 240). This program allows the researcher to code data into various categories called nodes. The researcher can see the relationships between the nodes and use these nodes to organize the data into more generalized themes that will inform the study's findings (Merriam & Tisdell, 2016). See Appendix E for the codebook developed in NVivo for this study.

I first began loading each transcript into the NVivo program. Loading the transcripts, called cases, in the program allowed me to quickly move data into the coding section. However, before I loaded codes into the program, I first condensed the codes from the margins into broad categories such as *Skipping Lessons*, *Additions Lessons,* and *Time.* Once I created the codes into the program, I copied and pasted related and highlighted data into those codes. Some data appeared to "fit" in numerous nodes, causing me to determine what more precise nodes needed to be created or if some codes were too close, causing redundancy. I conducted a second round of transcript review, determining more precise codes to become subcodes. Several rounds of transcript review eventually created a system of codes created as "parent" and "child" codes depicting a set of broad ideas related to the study (parent codes) and subcodes that were a more detailed description of the broader code (child codes). Examples of parent codes from this study are *Preparation, Lesson Materials, Time, Professional Development,* and *School Demographics*. "child" codes include *grade level preparation, individual preparation, lesson readers, lesson work pages, school size,* and *school category (rural, suburban, urban).* I tried to code all the data, even data that did not seem relevant to the study, in an effort to be complete in the coding process. I then looked for places where there was overlap or redundancy and moved data from one node to a node in which it better fit or eliminated a code that seemed redundant (Creswell, 2016).

The codes in the final codebook represented major themes and evidence supporting those themes taken from the transcripts. These themes and corroborating evidence appear in Chapter Four.

Summary

Data collection and analysis methods are at the center of any research study. This chapter reviewed the methodology used to create the survey and interview questions and rationales for using a mixed-method approach. A mixed methods approach is favored with data from different research approaches and can create more understanding of a topic than either method can do on its own. In this study, the survey created a baseline of ideas and decisions that teachers using the SSEC materials report drawing upon during science instruction planning and delivery. The interview portion of this study gives voice to individual teachers as they express how they come to the decisions they make about those materials.

Chapter 4: Findings

Introduction

This study employed data analysis collected from survey responses, interviews, and materials from fourth and fifth-grade teachers across the United States whose districts adopted *Smithsonian Science for the Classroom* (SSEC), a module-based science curriculum designed for grades K-5. This research study was conducted to answer these questions:

- 1) How do teachers report using instructional materials in elementary science during planning and delivery of instruction?
- 2) What modifications, if any, do teachers report making to elementary science instructional materials?
- 3) What rationales do teachers report for these modifications?

I begin this chapter by describing the respondents to the survey, interview, and materials requests. I collected survey data first, noted themes that emerged from that data, and formulated interview questions to investigate those themes further. After the interviews, I requested classroom materials from all twelve interviewees and received materials from four. The analysis presented in this chapter does not follow the research process in the order conducted. Instead, I presented the data from the survey, interviews, and materials under the research question to which it best relates. In Chapter 5, I summarize the findings and provide implications and suggestions for future research.

Survey Respondents

Fifty-four teachers responded to the survey, 47 females and seven males, and all identified as white except for one multiracial respondent. At the time of the survey, 25 respondents were fourth-grade teachers, 24 female and one male, and 31 were fifth-grade teachers, 25 females and six males. Teachers could complete the survey anonymously or provide a school email and enter a drawing for an Amazon electronic gift card. Of the 54 respondents, the emails provided by 25 respondents came from New York, Virginia, Massachusetts, Colorado, Connecticut, Pennsylvania, and Washington (see Table 1).

Table 1

Number of Survey Respondents Who Provided Emails Broken Down by State

State	# of Respondents who Provided Emails
Colorado	3
Connecticut	2
Massachusetts	2
New York	14
Pennsylvania	1
Virginia	2
Washington	1

Most of those taking the survey described their districts as suburban (65%), while rural and urban teachers were also represented (28% and 7.5%, respectively). The respondents ranged in teaching experience from one to five years to over 21 years, with the largest group falling in the 21+ year range (see Table 2).

Table 2

Teaching Experience of Survey Respondents

Years of Teaching Experience	Percent of Respondents
1-5	18.52%
6-10	18.52%
11-15	14.81%
16-20	14.81%
21+	33.33%

When the survey was administered in 2022, most of the districts were reasonably new to the Smithsonian Science for the Classroom instructional materials, with 60% reporting having used the kits for two years or less (see Table 3).

Table 3

Number of Years Survey Respondents Have Been Using SSEC

Number of years using SSEC Materials	Percentage
1	32%
2	28%
3	22%
4	18%

Survey Responses

Respondents to the survey reported on several topics related to the SSEC materials, including which modules they teach and how many years of experience they have teaching with these materials. The initial questions collected demographic information and were short questions requiring one answer. Several respondents did not complete the survey. I noticed that the number of respondents decreased when questions required more than one answer, such as those that asked respondents to check all answers that applied. This drop in response might be explained by time constraints, the respondent's inability to remember the details of a lesson or unit, or a desire to skip the extended questions. According to the consent form associated with the survey, respondents could skip any question for any reason. In total, 54 respondents began the survey, and at least 50 respondents answered most questions. Two of the questions in the survey were answered by 42 respondents. Appendix D contains a complete list of question descriptions and the number of respondents that answered each question. No statistical tests were run on data from the survey, and all percentages were calculated based on the number of respondents to specific questions individually.

Interview Participants

Seventeen survey respondents agreed to an interview. Of those seventeen, five did not respond to two emails requesting a date and time to talk. I subsequently scheduled twelve respondents, ten females, and two males, and interviewed them within two weeks of their initial survey response. Interviewees were from Colorado, Massachusetts, New York, Virginia, and Washington (see Table 4). In contrast to the general survey respondents, only five interview respondents classified their schools as suburban (41.6%), and seven classified their districts as rural (58.3%). The teaching experience of the interviewees ranged from three to thirty-one years. (see Table 5) Like the survey respondents, the most significant percentage of those interviewed had over 21 years of teaching experience. At the time of the interviews, five interviewees taught fourth grade, and six taught fifth grade. One teacher taught STEM to grades three, four, and five. Two teachers were typical education teachers who co-taught with a special education teacher. One teacher taught only fourth and fifth-grade science, and one taught only fifth-grade science.

Table 4

Interview Respondents by State

State	Number of Interviewees
Colorado	2
Massachusetts	1
New York	7
Virginia	1
Washington	1

Table 5

Teaching Experience of Interviewees

Years of Teaching Experience	Percent of Interview Participants
1-5	8.3%
6-10	25%
11-15	8.3%
16-20	16.6%
21+	41.6%

Interview participants also varied in the years they had used SSEC materials. Experience extended from one year to four years at the end of the 2021-2022 school year (see Figure 4.6). Two teachers had prior experience with Smithsonian materials, one teaching a previous series produced by Smithsonian, and one who piloted the SSEC materials before their availability for purchase. Unlike the survey respondents, the most significant percentage of interview participants had at least four years of experience with the SSEC materials. Many interviewees noted that the pandemic impacted their science teaching and the implementation of new SSEC modules. In particular, the COVID pandemic delayed the implementation of new state tests aligned with the NGSS or state versions of the standards. Consequently, teachers had to adjust their teaching to accommodate both teaching the SSEC materials and preparing students for the test based on old standards. Three teachers mentioned that they taught a combination of old units and SSEC modules to make these accommodations.

Despite the interruption in implementation and the variance in the number of modules teachers taught, all fourth-grade interviewees had one module in common, *How Do Animals*

Communicate?, and all fifth-grade interviewees had two, one of which, *How Can We Provide Water to Those in Need?*, was selected as the focal fifth grade unit for this study. Some districts purchase their modules, and therefore, budget decisions, such as when funds are available for module purchase, determine how many modules each grade level teaches and when new module implementation will occur. However, the other interviewees reported that the materials came from a regional science distribution center on a rotating schedule.

Table 6

Number of Years Interview Participants Have Been Using SSEC

Years using SSEC Materials	Percentage of Interview Participants
1	25%
2	0%
3	16.6%
4	58.3%

Classroom Materials

Depending on their grade levels, I requested instructional materials from the twelve interviewees from one of the modules. Four of the twelve, Ireland, Jack, Carl, and Shelley (pseudonyms), responded to my request. Ireland and Carl sent complete slide decks for the fifth-grade unit, Shelley sent sample lesson slides from the fourth-grade unit, and Jack sent teacher and student notes for the fifth-grade unit (see Table 7). Shelley and Ireland noted that their grade-level colleagues also used the slides, indicating that all students in the grade level learn science with the same slide materials. Carl teaches science to both fifth-grade sections in his elementary school, and Jack teaches in a self-contained classroom, teaching science to his class only.

I used responses from all phases of the study to answer the following three research questions and provided examples from the classroom materials to support the responses from the survey and the interviews.

Table 7

Respondents By Grade, Unit, and Materials Provided

Teacher	Grade Level	Unit	Materials Provided
Ireland	STEM Grades 3-5	*How Can We Provide Freshwater to Those in Need*	Slide deck of the entire unit
Carl	5	*How Can We Provide Freshwater to Those in Need*	Smartboard slide deck of the entire unit
Jack	5	*How Can We Provide Freshwater to Those in Need*	Teacher notes, copies of student notes, list of online resources used to supplement the unit
Shelley	4	*How Can Animals Communicate Using Their Senses*	Slide decks for lessons 2,3,4,6,10

Research Question 1: How Do Teachers Report Using Instructional Materials in Elementary Science During The Planning and Delivery of Instruction?

The initial training teachers receive on new instructional materials can significantly influence the use of those materials in the classroom. Implementing a new science series with multiple components can be daunting. The SSEC's materials include teacher manuals containing lessons, information about the NGSS, pacing suggestions, and teaching notes for teachers. Additionally, the materials include student readers with non-fiction stories accompanying particular lessons, worksheets, and most of the physical materials for a class to complete the hands-on investigations. For some units, teachers may have to supply water or other general supplies, such as paper towels. Where living organisms are required, teachers follow a procedure set up by the kit distributor to receive them in a timeframe that coincides more specifically with when the organisms are needed for instruction.

Teachers need time to familiarize themselves with new materials to determine what is being taught and how to set investigation materials up for student use. Recall from Chapter Two that the science standards to which the SSEC materials align require a departure from traditional science teaching and learning methods. Most participants in this study have significant years of teaching science, which traditionally meant teachers disseminating facts as students took notes and memorized those facts to be used to answer test questions based on recall. During traditional science instruction, students followed step-by-step investigations to achieve a specific "correct" outcome. As teachers learn the material in the SSEC modules, they must also become comfortable with a different view of teaching and learning science, where students build their knowledge through a series of investigations from which they draw conclusions and deepen their understanding of concepts and practices throughout the unit.This step away from traditional science teaching and attention to how all three dimensions of the standards are woven into the fabric of the unit is vital for student learning. Therefore, receiving adequate initial training is crucial, and must focus on not just what to teach but how to teach, specifically, how teaching these modules differs from traditional science teaching.

In this study, teachers' opportunities to learn how to use the SSEC materials varied. Some teachers reported that they were trained directly by the Smithsonian staff, some were trained by in-district trainers such as curriculum coordinators or STEM teachers, and some trained themselves or trained with colleagues. The most significant percentage of study participants were trained by regional trainers employed by science centers, such as BOCES, that provide educational services to multiple schools in an area (see Table 8).

The nature and intensity of training the SSEC instructors received are beyond the scope of this study. That would have required a different sampling strategy. However, by the nature of their job description, it would be reasonable to think that trainers are likely to have a more profound knowledge of the three-dimensional nature of the standards, how the SSEC lessons incorporate these dimensions, and how the scope, sequence, activities, and assessments work together to help students master the standards. As generalists, however, many elementary teachers teach other subjects, and those in this study consistently reported that lack of time is a constant challenge to science instruction and training. Therefore, it is unlikely that those who trained themselves on the modules would have the time to gain a depth of knowledge about the relationship between the materials and the standards a trainer possesses. This study only collected information regarding initial training. However, it is common for trainers to supply teachers with their contact information as a source of assistance with difficulties or questions about implementation after module training, expertise to which classroom teachers who train themselves would not likely have access.

Table 8

Sources of Initial Training on SSEC Modules Taken From Survey Results and Interview Participants

Source of Initial Training	Survey Respondents and Percent		Interview Participants and Percent	
	Survey Respondents	Percent of Respondents	Interview Participants	Percent of Participant
Regional Trainer	25	50%	5	41.6%
Smithsonian Trainer	9	18%	3	25%%
In-district Trainer	3	6%	1	8.3%
Trained with Colleagues	6	12%	2	16.6%
Self-trained	7	14%	1	8.3 %

Districts that adopted *Smithsonian Science for the Classroom* as their elementary science curriculum were the population from which the survey sample originated. Most survey respondents, 76%, said they had little or no control over which science topics and skills they teach. It stands to reason that districts expect teachers to use the district-adopted curriculum. Surprisingly, more than half, 54%, of survey respondents reported having a moderate to a great deal of control over the number of minutes they spent on science instruction compared to the 46% of respondents who reported little or no control over time. I expected the percentage of teachers who did not control how long their science lessons were to be much higher as the literature and interviews conveyed that science instruction is hard to fit in given the demands on time and the emphasis on ELA and mathematics. However, it is possible that these survey results were related to the grade levels investigated in this study and could be different if teachers of other elementary grades were included. Interview respondents also reported having control over the number of minutes they spend teaching science. According to interviewees, science lesson length ranged from 30 minutes, including transitions, to 60 minutes and from two days per week for five weeks to five days a week for the whole school year. The role of time in science instruction will be discussed at greater length later in this chapter.

A logical expectation of a district is for teachers to use the district-adopted series or module materials, especially when the modules provide all components needed to deliver instruction. However, survey and interview data point toward teacher discretion regarding the modules' components and how to use them in daily lesson preparation and delivery. Interviewees described skipping whole lessons for various reasons, making cuts to sections of lessons, substituting materials, and modifying work pages and offered explanations for these changes. Additionally, survey respondents listed materials from the Internet that are not part of the SSEC module materials that they use regularly during science instruction in their classrooms. Therefore, it is notable that while 52% of survey respondents reported having little or no control over which SSEC materials they use during their lessons, virtually all interviewees described making modifications, indicating that they did have control over what and how they use materials in lesson delivery. Example materials sent by interviewees provide evidence of these changes and will be described later in this chapter.

Most SSEC units are fifteen lessons long and are generally designed to be taught over twenty class periods of 40 minutes each, as some lessons take more than one class period to complete. When a regional science center delivers the modules on a rotating basis, the typical duration for a teacher to have a module is one marking period or ten weeks, which should be enough time to finish the unit. Many teachers report that they often split the marking period between science and social studies instruction, leaving only five weeks or 25 lesson days to complete the science modules. Three interviewees reported that their districts owned their units, allowing for greater flexibility for when and how long teachers can spend teaching a module. The other nine interviewees reported that the materials came from a BOCES or a similar regional science distribution center, which distributed, retrieved, and scheduled delivery and pickup on a rotating basis out of teacher control.

SSEC teacher manuals contain front-matter information about the curriculum and the standards in general. For any given unit, the manual contains a pacing guide, an overview of each lesson, and an identification of the Scientific Practices, Disciplinary Core Ideas, and Crosscutting Concepts of the Next Generation Science Standards addressed in the unit. Teachers in the study indicated that they used these materials when planning out the units.

Planning and Delivering Instruction

Over time, teachers develop personal styles of planning and delivering instruction. Science instruction is unique because there are often more physical materials to prepare in science than in math, social studies, and ELA, the other areas of instruction for which elementary teachers typically prepare. In this study, many teachers reported that because their materials come from a regional science center in crates, they must retrieve materials for the investigations from the containers and prepare them for instruction. Preparation may include putting pieces together, such as adding batteries to flashlights, setting up investigations or distribution stations, and ordering live materials for specific lessons. Teachers also need to copy the worksheets provided in the modules. This preparation is an area that both the survey and interview respondents noted as “time-consuming” and “overwhelming” and played a role in decisions about what lessons they teach and how they choose to teach them. While the survey responses reveal general information about how the preparation of materials plays a role in making changes to instruction, the interviewees shared more detailed information about how they prepare at both the unit and lesson levels and how this preparation influences their decisions about teaching the SSEC lessons. The instructional materials shared by the interviewees provide evidence of how those changes are incorporated into their lessons.

Unit Planning

The variance in methods of module preparation described by the teachers seemed directly related to their teaching assignments. For example, in settings where multiple teachers in a grade level teach the science curriculum, the colleagues plan as a team and can make decisions as a team, even when one person takes the lead. Those who are the sole provider of science instruction for their building typically plan alone without input from others. One interview respondent, Ann, noted that she is the only science teacher at her grade level in her building but plans the entire year of science with her district counterparts from other schools at the beginning of the school year. From there, they plan individual lessons independently but stay on the same schedule as best they can. "We have created unit design plans and unit matrixes. I look at those and plan out, looking at how many days each lesson is supposed to take." Two respondents said they created detailed notebooks during their first year teaching the modules and now use those to refresh themselves about the content and focus of each unit as they prepare to teach it.

Although differing in the amount of contact, all but two interviewees have some collegial support as they work through the SSEC modules. Eight of the twelve interviewees cited working in grade-level teams to plan the overall module and often, at that time, determine what lessons they might combine, skip, or modify in some way.

Roberta works with her grade-level colleagues when preparing to teach a module and describes their team approach:

> There's four of us, and one person takes the lead on the team for science, rotating by quarter. You would do it once a year, that you're in charge of science. And then, that person takes the materials, and we create Google Slides that help as we teach. And then, we pick and choose what we can pull out that we want to hit to make sure we hit certain parts of the unit. Then we'll also try to link some of the videos from the [Carolina] website into our teaching slides.

Another teacher, “Molly”, stated that she and her colleagues also plan as a team, but they rely on one colleague to direct the team:

> So when we do that, there's one person at the grade level that we kind of collectively deem is our science guru. So this is all done with the okay of her. I won't use her name, but it's all done with her. She has the most expertise in teaching science and the most expertise, I believe, in just fully internalizing and knowing science material. So we go through, and we say, "What's the overall gist here of the whole unit? And then, if there’s a lesson or two that seems to go off on a slightly different tangent, as I do find many of them do, that would be something we wouldn’t pick. We always use the standards as guidelines for what we need to pick.

One interviewee, Shelley, is the unofficial team leader for science for her grade level. She leads the team discussions regarding science instruction and sent examples of slides for Lessons 2, 3, 4, 6, and 10 of the fourth-grade SSEC unit, *How Can Animals Use Their Senses to*

Communicate?. She noted that she and her fourth-grade colleagues use a slide deck in the classroom, initially created by a regional Smithsonian trainer for virtual instruction during the pandemic. However, she and her colleagues found them so helpful and complete that they still use a version of them in their instruction. They use the slides as the primary tool when planning the unit instead of using the teacher manual. The grade level team updates them every year if they feel a need. The materials Shelly provided suggest that the slides follow the lessons in the teacher's manual, which would make sense, seeing that a regional trainer prepared them. Still, the team decides which lessons they will teach, which they will cut, and which they might combine. During classroom instruction, the teachers then use their discretion and make their modifications. Shelley stated, "One teacher does more extensions because she likes the readings. Other teachers skip more lessons than I do." This description shows that although the teachers use the slides across the grade level, the student experience may differ depending on the teacher.

This scenario is similar to what other interviewees describe. Molly, a fourth-grade teacher in a suburban school, describes her situation when planning for the unit. When analyzing this segment of Molly’s interview, I noticed she does not feel confident in her science knowledge and relies on a colleague to make decisions about curriculum cuts. However, she feels confident in identifying a tangent that doesn’t relate to the task at hand and, therefore, can be eliminated, which is confusing. Recognizing a curriculum “tangent” would seem to depend on scientific knowledge.

Katie, another fourth-grade teacher, describes a similar person who takes the lead in her school preparing to teach the modules:

> So she [the grade level colleague] has, on her own really, been able to lead us and give us some guidance on like, okay, we need to make sure that this particular New York State

standard, next-gen standard has us needing to learn about, I'm thinking about the changing earth one that we start with, where we learn about the weathering and erosion and we have to make sure we hit that

Consulting the standards when teaching science is paramount. However, the above statements suggest that these teachers focus on the Disciplinary Core Ideas only, the science content component of the standards, when deciding what to teach and what to cut, and not the standard as a whole, which would include the Scientific Practices and Crosscutting Concepts which is significant because the three dimensions of the standards are designed to work together to contribute to student understanding and provide crucial steps in the progression of the standards for science learning over time. Further, the SSEC units are designed to give students multiple opportunities to engage in the practices used by scientists, such as collaborating and drawing conclusions from the evidence and making connections between the various disciplines in science, for example, chemistry and biology. Each lesson is designed to focus on specific content (DCI), specific practices employed by scientists in their work (SEP), and specific areas where students can see the connections between the different science disciplines (CCC). Therefore, as a whole, the unit creates several opportunities for students to interact with all dimensions of the standard. By cutting lessons, these interviewees may be focusing on making sure students learn the science content described in the standard but unintentionally eliminating portions of the lesson that address the Scientific Practices or Crosscutting Concepts and, therefore, do not address the standards fully and do not allow students ample opportunities to gain complete understanding of the standard.

Ireland, a STEM teacher for grades three through five in a suburban school, occupies a unique position in her district. She works closely with the teachers in her building and teaches in the STEM lab. The teachers and Ireland employ a team approach to the units. She prepares the module materials for classroom teachers and in her STEM lab. She creates two slide decks: one containing the lessons teachers deliver in their classrooms and one she uses to teach in the STEM lab. The slides closely follow the teacher's manual.

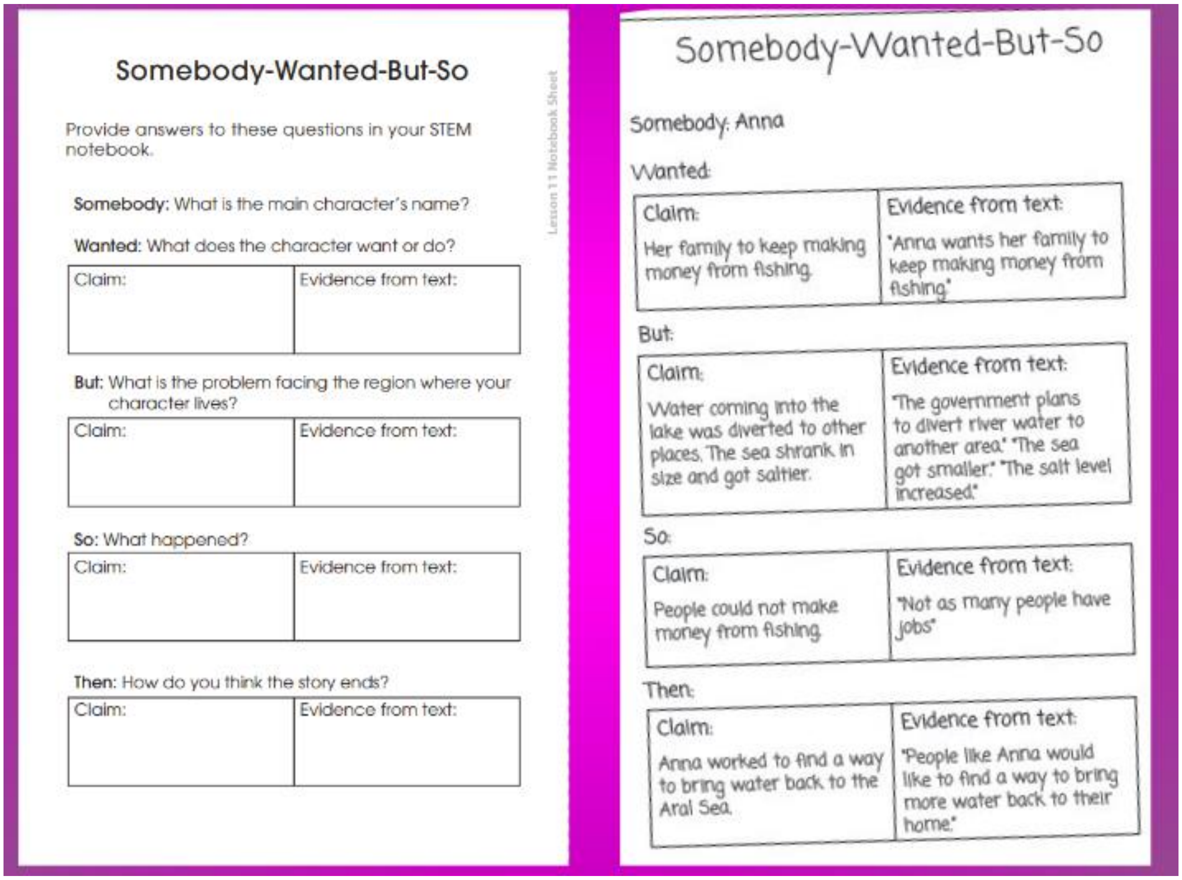
Ireland explained:

> And the Smithsonian has the standards, and it tells us what standards are being taught in this lesson, and we really want to teach that. We have yet to figure out if we are teaching it based on the lessons. We're just trusting that Smithsonian did the work.

Ireland said she added information to the slides to help the teacher move the lesson along. For example, some slides in the slide deck are meant just for the teacher. Figure 4.1 shows an example of a slide in the slide deck that can help the teacher lead the students in the right direction if necessary or used as a guide for how the developers anticipate the students might respond to the prompts.

Figure 4.1

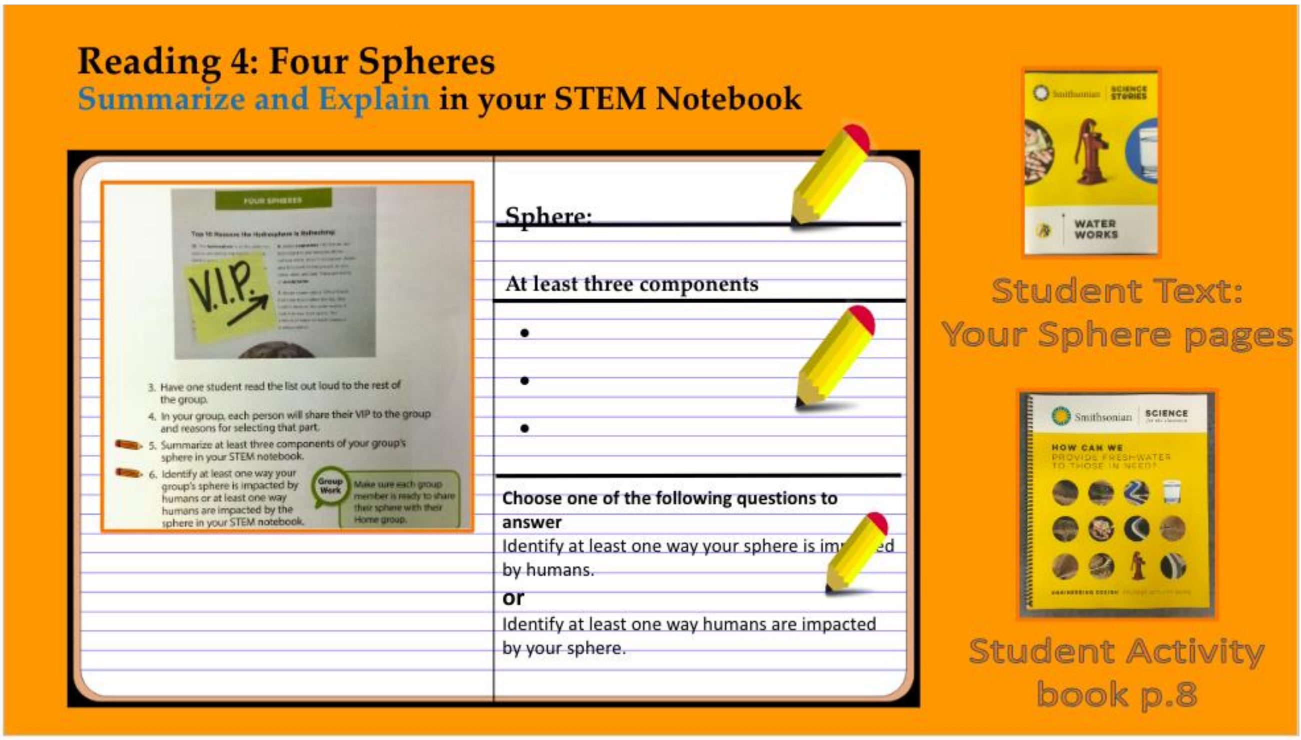
Sample of Slide Meant for Teacher Eyes Only



Teachers also have slides in the deck that give students clarity regarding which materials they need to use, where to write, and what they should look for as they go through the lesson. Figure 4.2 provides a slide sample that shows students what materials they need to use, how to set up their notebooks, directions, and where students need to respond. Using the same slide style that shows students where to write, Ireland can help students in grades three through five become familiar with her "system," saving time for teachers in the classroom and for her students in the lab. Using this same design for the three years that they are in the building, students become familiar with the symbols for where to write and what books to use, which can eliminate confusion and save time.

Figure 4.2

Sample Slide for Students From Ireland's Slide Deck for Teachers



Ireland meets with each classroom teacher individually and shares her plan for which lessons from the module the classroom teacher will teach and which she will teach in the STEM lab. She preps and supplies the teachers with all the needed materials and describes what the teacher needs to cover before the students come to the lab for instruction. She serves as the point person for any questions or troubleshooting. Though many interviewees mentioned a team approach, Ireland's position allows for the closest contact between colleagues as she works with them on the unit.

She stated:

> Well, we schedule it together. The classroom teacher and myself, what works for their schedule, what works... so, we have a lot of freedom there to figure out when to do that. We could either do it at the very beginning when they get their materials, to go through what the materials are, go through the Google slides, look at the curriculum, the teacher manual, and talk about what I've noticed. For example, if one of their lessons says to reflect on the hands-on lesson, which would've been done with me in the STEM lab, I'll highlight things like that for them, be like, "This is a moment where we need to be on the same page. This is important to me to have seen your students before you get to this lesson." Or, "If you get to this lesson before I see your students, note that this is a part of it. So, you'll have to edit, you'll have to be creative," which is what we're always doing. But it's so great to have someone point that out to you.

Maya, a fourth-grade teacher in a suburban school, mentioned that a district science curriculum person travels between schools. However, Maya does not have the type of interactions described by Ireland. Her conversations with the science coordinator focus more broadly on the modules, and she does not appear to receive the assistance in preparation that Ireland provides for her colleagues.

Maya explained how she works with the curriculum coordinator:

> So when they [the curriculum coordinator] would be at our school, I would ask them at this school or the school you're at, does the teacher see this with the kit? And they would go and ask the other teachers and then they would come back and ask me questions as well. So there was that communication, what was working, what wasn't working. And then our third-grade science teachers, they would ask me things. Even

though we were not teaching the same concept, just asking questions about, 'Are you running into this with the kit as well?'

Other interviewees plan science units on their own. Interestingly, two interviewees, Jack and Carl, both fifth-grade teachers who plan for the units without colleagues, were the only respondents who noted that they follow the modules and hit every lesson. They also added content to each module, a significant departure from the other interviewees, who described having to pare down the materials due to time constraints for teaching and preparing materials.

Carl teaches fifth grade in a small rural school district and provided a slide deck for the unit, *How to Provide Freshwater to Those in Need?* He described his students as mainly impoverished, with limited experiences outside of their community and low academic skills. Carl approaches the SSEC units by reviewing the materials to refresh his memory. He then begins each unit with supplementary content collected from the Internet and unit-related materials he has acquired over his twenty-plus years of teaching. In the interview, Carl shared that he does not skip any lessons but may only do some parts of each lesson as described. Specific examples of the content Carl adds to the SSEC units and his justifications for doing so are presented later in this chapter.

Jack is also a fifth-grade teacher with 31 years of teaching experience in a suburban district. He provided note samples from a science video and two lessons from *How to Provide Freshwater to Those in Need?* He also supplied a list of video sites he often uses to supplement his science lessons throughout the year. In his interview, Jack explained, "I did every single lesson, I used every single material, and we kept a science journal, a composition book that was filled up from the front page to the end." He later added that he uses "every one of the student guides (activity books) and student readers, including the ones in Spanish for my students who do not speak English." Specific examples of Jack's instructional materials are discussed later in this chapter.

Lesson Planning

The components of the SSEC materials are designed to work together to create comprehensive lessons that address the NGSS standards. The front matter in the teacher's manual outlines the objectives for each lesson, the Science and Engineering Practices, Disciplinary Core Ideas, and the Crosscutting Concepts of the specific standards addressed in each lesson. Each module contains lessons where students read, write, and support their ideas with evidence from hands-on investigations. Each lesson begins with a listing of objectives, some background information for the teacher, a list of materials needed to complete the investigation, and step-by-step instructions for preparing to teach the lesson. Survey respondents (74%) said they use the materials consistently to guide the structure and content of their lessons, and interviewees described how they use them during their lessons. The lesson plans in the teacher guides contain diagrams, photographs of material setups, questions to ask students with examples of potential responses, and teacher tips. Margin notes describe where the specific scientific practices and crosscutting concepts of the standards appear in the lesson. There is at least one extension activity at the end of each lesson, followed by a rubric that defines the concepts and practices of the lesson and lists indicators of success and difficulty to assess student performance. The final two lessons in each unit serve as assessments of the student learning of standards addressed in that unit. The rubric accompanying the final two lessons is much more extensive than those of individual lessons and addresses each individual Scientific and Engineering Practice, Disciplinary Core Idea, and Crosscutting Concept for all of the standards addressed in the unit.

The teacher guide identifies the lesson steps, divided into three labeled sections. The first segment, *Getting Started,* is an introduction to the lesson. It often includes a brief activity where students write observations of a photo depicting the focal point of the lesson or answer one or two questions in their STEM notebooks, followed by a brief whole-class discussion and sharing of ideas. The next segment, *Activity,* provides the procedure for leading the investigation that the students carry out using the materials, activity books (activity instructions), and student readers offered by the Smithsonian. Lastly, *Bringing it All Togethe*r is the segment devoted to student sense-making of collected data and connecting the work to previous activities in the unit, expanding their understanding of the unit objective. This section provides questions to assess student ideas and allows students to make claims based on data collected during the investigation and back them up with evidence.

According to interviewees, when planning individual lessons, some teachers try to touch base with teammates to troubleshoot, share materials, or keep pace with one another, but overall, planning the specifics of a lesson and setting up materials is generally an individual endeavor. During the interview phase of the study, teachers described mapping out a weekly or biweekly calendar, noting how many days were needed for each lesson, creating slide decks, or adjusting slide decks created by a colleague, and preparing the physical materials such as note pages and hands-on materials as routine for lesson preparation. In certain instances, such as with Ireland and Roberta, the teachers have developed a system where one individual is responsible for creating these lesson materials for colleagues. However, these were exceptions rather than the norm. Still, many of the interviewees described similar methods for lesson preparation.

Molly explained her method for lesson preparation:

> I take the teacher's edition. That's like a bible to me. I take the teacher's edition home and I make sure I read through the lesson, rather, pretty thoroughly. Even the night before, I will have to revisit the lesson I'm going to teach the next day. Now back when these units were completely new, and I was teaching them for the very first time, I had to read it, and then I had to write my own notes. So it's actually my notes that I have with me during the lesson and the teacher edition in case I need it as a reference. Now that I am more familiar with the units, I don't need to do the notetaking step.

Ann made a similar reference to how her first year of planning created a framework for how she plans her lessons now. Like Molly, as she became more familiar with the material, she felt she no longer needed the extra steps for preparation.

She explained:

> So, the first year that I taught them, I made a really detailed science notebook so that it has all of the focus questions, hypotheses, data, CERs, all of that, and then I kind of use that as my skeleton. So I'll just get whatever materials I need, I'll do all of my copying at the beginning of the unit, and then, like I said, I just set up any materials. But if it is one that I'm not super familiar with, like I don't remember specifics about it, I'll usually spend more time reading through it, but I usually just glance through it just to remind myself of what's in it, but I rely on my own personal science notebook that I've made.

Some teachers note that decisions about what lessons they might modify or skip occur when planning for lessons individually based on systemic issues and personal beliefs. As generalists, elementary teachers are often responsible for preparing to teach all subjects except art, PE, and music. As Ellie pointed out in her interview, she makes decisions based on what she thinks students will like or the amount of preparation time the investigation takes. She feels doing it all is not feasible, especially with one daily planning period.

> I take out the teacher guide. I look through it. When I'm cutting, I'm cutting things that were going to be least interesting to my students. So every year, it's a bit different, depending on the group. So I just kind of go through and I think,' What is the big picture? What is it that I want them to learn? What is our standard?' and then I just cut out activities that I don't really think…. they're not building on that skill so maybe that's something that I take out. The ones that require so much prep time.

Katie made a similar reference to the intensity of lesson prep.

> They [the lessons} are excellent in theory. There's some really good ones that we do, but they are extremely timely, time consuming in setting up, time consuming in having the children do it. And we feel like elementary teachers are really only given one chunk of prep time. And in that time, supposed to do a lot of different things. And there are times that the hands on portion of the kits could take up one or more of our planning times just to set up, not even have the kids do. Which is upsetting, which is upsetting because some of the stuff is really good. It just is at times not realistic in what we're able to adequately do and keep our sanity, if I'm being honest.

It is important to note that Ellie and Katie describe a situation that all elementary teachers face. It is typical for a teacher to have one planning period per day. In that time, they are expected to take care of personal needs, attend to email, possibly connect with parents or administrators, plan lessons for all subjects they teach, and set up science materials. Ellie and Katie share that some of the science investigations are so labor intensive to set up, and there is often not enough time to do so and still attend to other required tasks during one planning period. What is challenging about decision-making based on preparation time is that some lessons may be labor intensive because they focus on key ideas and skills that students need to build. Skipping them may mean students miss a significant segment in the learning progression of the unit.

Katie shared a way she and her colleagues tried to address the issue of the intensity of lesson preparation that would save time and space and allow her entire team to carry out investigations using one setup. “We were able to use our second classroom (space used by her co-teacher for direct instruction) to set up the materials, and then the classes came through that room.” While she said that the system allowed for more investigations to be completed, she also mentioned that that room would not be available for science going forward. It was a good solution but could not be sustained. Katie described a second option that she and her colleague had employed previously. “Another time, myself and another team member prepared the materials, and then we just shifted them from room to room.”

Katie's point is an important one. Teachers need space to set up and store materials between lessons. For example, in a unit focusing on erosion and deposition, students create models in containers called stream tables 12 inches wide and 24 inches long. Students create a mixture of sand, clay, and small pebbles to represent earth materials and pack that material at one end of the stream table. The stream table is set on a surface at an angle so that students can run water through the materials and see how the earth's materials are moved and changed to model erosion and deposition. From this data, students make claims about erosion and deposition based on how steep the angle of the stream table is, how fast the water moves, where it collects, what materials move the farthest, and what earth materials travel down the length of the stream table to the drainage basin placed on the floor. Students then use the data collected to make claims and create solutions supported by evidence around erosion and deposition. These tables are used in several lessons and require storage and a place to dry between uses. This kind of space may only sometimes be available, adding another challenge to using the materials and thus forcing teachers to skip or modify the lessons with demonstrations instead of hands-on experiences for students.

Research Question 2: What modifications, if any do teachers report making to elementary science instructional materials?

Despite the high percentages of study respondents who reported using the SSEC materials as a guide and structure for the lessons, common themes emerged from the data suggesting that teachers also modify the materials. Skipping lessons or portions of lessons and modifying materials such as work pages were noted in responses from the survey and interview participants and evidenced in the instructional materials collected. Rationales for making changes to module materials also shared some common themes. In this section, I explore common modifications made to the SSEC materials. Often, during the interview phase of the study, a participant's explanation of the changes they made to the SSEC materials would be accompanied by the rationale for making those changes. Therefore, it is sometimes difficult to separate the changes from the rationales in this section. However, a more in-depth explanation of the rationales provided by teachers and examples appear later in this chapter.

Deletions

Survey recipients provided reasons for skipping lessons or portions of lessons from the SSEC materials. Of the 40 participants who reported skipping lessons, an overwhelming 36 noted that they skipped because they did not have enough instructional time to teach the lessons as designed. Ten interviewees added that they had to cut either whole lessons or portions of lessons to fit their schedules, and nine of them shared specific examples of what types of lessons they skipped and why. Three interviewees said they tried to hit at least part of every lesson in a module. Katie explained that as she looks at the lessons, she decides if she could do them differently than how the lesson prescribes to save time.

She stated:

> …This particular lesson, maybe it's a reading-only lesson that Smithsonian has. Well, do we need that? Can we shorten that? Can we give them another article on weathering and erosion, that maybe is more doable to their level and give them information, without having to use the Smithsonian readers, kind of thing.

Laura, a fourth-grade teacher in an integrated co-teach class, stated that she feels she needs to cut much material from the SSEC materials. Like Ireland, her decisions are partially based on what she feels are her students' capabilities.

Laura explains her position:

> In theory, I think they're a really great system to use. However, in my classroom setting, it's just not feasible for students to complete a lot of the work. I focus in on more of what it is that the kids really need to take away from the lesson, and that's what we do. I remove content or remove part of the lesson and don't always have the students do the experiment but have the students watch the experiment. Because I know there's the Smithsonian we can show the video of it. I've done that.

It is essential to note that the video Laura refers to is included in the module for the teacher to watch before teaching the unit. The video shows each lesson in its entirety, including the outcomes of the hands-on portion, and thus reveals the learning that the lessons are designed to develop. Because it is meant as a teaching tool that helps prepare teachers to teach the lesson, it describes what students are meant to notice, thus turning the investigation into a video-based lecture.

Three interviewees mentioned that they often do not do the culminating lessons. Diane shared that she only sometimes finishes a unit. “The culminating activity, culminating lessons, are usually pretty big. So if something is going to get cut, it is usually that.” It is unclear whether she meant she skips the lessons because of the preparation, the time they take to execute, or a combination of both. Roberta also said she tries to “hit the ones with the most content in them.” She also mentioned that “we did not have time to get to the end lessons.”

Roberta was one of several teachers who mentioned that they did not get to the final lessons. While cutting any lessons has consequences, cutting or not getting to the final lessons creates a particular issue. The content, practices, and crosscutting concepts come together in these lessons, which are the summative assessments for the unit. However, more importantly, by combining the practices, content, and concepts that appear across many units, students can experience how these come together to help explain what is happening in the final investigation. Shelley is another teacher who is having the same issue.

She shared her frustration with not being able to finish the modules in their allotted time:

> But like I said, we never finish anything. So I got trained, we saw the awesome culminating activity at the end. I’ve never gotten to the egg drop and that is something that I’ve always wanted to do and you never get to it.

In the final two lessons in each unit, designed as a summative assessment, students synthesize the learning from the unit and engage in scientific practices and higher-order thinking. The egg drop lesson, to which Shelley refers above, is the culminating activity designed to be the summative assessment lesson for a fourth-grade unit on energy and collisions. By missing those lessons, students miss synthesizing six of the eight Scientific and Engineering Practices and four of the seven Crosscutting Concepts (see Table 9). Further, by eliminating the culminating activity lessons, students miss the opportunity to answer the question on which the unit is based and miss a chance to understand why it was important to study the phenomena in the first place.

Table 9

SEPs and CCCs Featured in Egg Drop Lessons

Scientific and Engineering Practices (SEP)	Crosscutting Concepts (CCC)
Using Model	Cause and Effect
Asking Questions	Energy and Matter
Planning, Carrying Out Investigations	Scale, proportion and Quantity
Constructing Explanations	Systems and System Models
Analyzing and Interpreting Data	
Defining Problems	

An extensive rubric accompanies these combined lessons so teachers can assess student understanding of the content and the Scientific Practices and Crosscutting Concepts that were the unit's focus. Teachers who do not "get to" these lessons cannot assess whether students have successfully achieved the goals of the unit standards and are ready to move on in the progression of the standards as outlined in the NGSS. However, none of the interviewees noted that these lessons are designed to be a summative assessment, nor did they recognize the scientific and engineering practices that students miss. One interviewee noted that even though she typically does not get through the unit, she tries to develop a summative assessment. She did not explain how or if she included the practices and crosscutting concepts in this endeavor. As noted previously, a number of teachers in this study associate knowing factual information as the most critical aspect of science instruction. Ireland, the STEM teacher, has been working with grade-level teams and administrators for quite a few years to try and make room for all four units per grade level but notes they have yet to be able to finish a unit due to time. "We have gotten as far as eleven or twelve lessons. We have never made the full fifteen within the time allotted." She notes that she and the teams have determined to stick with ten lessons per unit.

> I have definitely experienced being able to pare down to about ten lessons, and based on our schedule, I think that’s how we are going to have to run it. And I’m not saying lessons one through ten or eleven, just as a whole, ten lessons. And it’s going to be based on our experiences as teachers.

Carl, an experienced fifth-grade teacher, mentioned during the interview that he does not skip entire lessons, but there may be portions of the lessons that he does not do. Like Ireland and Laura, he also bases some decisions on what he feels his students can do and what is too difficult for them.

He stated:

> Some of them [the lessons] have lengthy writing pieces and things and I might not include all of that just for time’s sake, but I usually try and hit at least the basic basis of each lesson that they want to get across, the main idea of each lesson. I may not do everything they expect the kids [to do] and some of the stuff, for our district, it’s just a little bit above what these kids can even do.

Molly also deletes lessons but for a different reason:

> We go through and we say, “What’s the gist of the whole unit? Then if there’s a lesson or two that seems to go off on a tangent, that would be something we don’t pick. If it sounds

like it doesn't quite address the standard, it's okay for us to cut it as long as it doesn't wreck the flow of what we're driving at.

As noted earlier in this chapter, Carl said he tried to hit every lesson but did not do every portion of each lesson. Table 10 shows an example of another type of deletion Carl has employed in the fifth-grade unit. In this lesson, Carl not only eliminated some of the objectives.

Table 10

Sample Teacher Modification of SSEC Lesson Objectives

Lesson 5 Objectives per SSEC Teacher Manual	Lesson 5 Objectives per Teacher Slide
Explore the structure and function of various tools in order to design a system for pumping water vertically.	Design a system for pumping water vertically.
Communicate possible solutions to failure points encountered during system testing in order to inform improvements to the original design.	Analyze failure points and improve design.
Evaluate whether all but one variable was controlled during two separate design tests such that the two tests can be considered a fair test.	Create a fair test between two designs with only one variable.

put forth in the module but also substituted some of his own objectives for those in the unit material. At first look, one might think Carl has reworded the module objectives to make them more "kid-friendly" for his students. However, this lesson in the module provides an opportunity for students to intentionally look at the structure and function of the parts of the system presented. This direct reference to the crosscutting concept, Structure and Function, is eliminated from Carl's list of objectives. Looking at each system component and exploring how the shape and its properties can help a system work is a deliberate step in this lesson to allow students to focus on the parts of the water transfer system students create.

Communicating ideas with others is a strategy used by engineers in the field. Students must consult with other students to share and critique ideas and decide how to proceed when completing a task. Carl's objectives indicate that students may not specifically attend to these practices and Crosscutting Concepts and, therefore, miss some vital experiences.

Each SSEC unit contains a lesson-by-lesson list of scientific practices featured in the lesson. Because it is common for students to engage in more than one scientific practice per lesson, the teacher manual lists the practices as focal practices or supporting practices. As noted in Table 11, students can participate in the practices multiple times throughout the unit if all lessons are taught (see Table 11). When full or partial lessons are eliminated, or substitutions made, such as in Carl's work, students miss the opportunity to do that scientific work.

Table 11 *Focal and Supporting Science and Engineering Practices by Grade Level Unit*

How to Provide Freshwater to Those In Need (Grade 5)	How Can Animals Use Their Senses to Communicate? (Grade 4)
Focal Science and Engineering Practices	
Obtaining, evaluating, and communicating information (10 Lessons)	Developing and using models (7 Lessons)
Analyzing and Interpreting data (7 Lessons)	Analyzing and interpreting data (5 Lessons)
Constructing explanations (6 Lessons)	Engaging in argument from evidence (9 Lessons)
Defining problems/Asking Questions (6 Lessons)	Obtaining, evaluating, and communicating information (5 Lessons)
Developing and Using models (5 Lessons) Constructing explanations (6 Lessons)	
Designing solutions (4 Lessons)	
Supporting Science and Engineering Practices	
Using mathematics and computational thinking (3 Lessons)	Defining problems (2 Lessons)
	Planning and carrying out investigations (4 Lessons)
	Using mathematics and computational thinking (1 Lessons)
	Designing Solutions

Survey questions asked teachers to classify how often their students employed the focal or supporting practices during their last science unit into one of four categories: more than half of the lessons taught, less than half the lessons taught, during every lesson, or not at all. On average, 44 of 55 survey participants responded to all nine practice-related activities listed. Eleven teachers either did not answer the question about the practices or addressed specific practices, but not all (see Table 12).

Table 12

Teacher Ranking of Instructional Time Spent in Practice Related Activity

Practice	During Every Lesson		More Than Half of the Lessons Taught		Less Than Half of the Lessons Taught		Not at All		Total Number of Respondents
	No. of Teachers	Percent Of Total	No. of Teach-ers	Percent Of Total	No. of Teachers	Percent Of Total	No. of Teachers	Percent Of Total	
Generate Scientific questions	8	18%	12	29%	16	37%	7	16%	43
Conduct Scientific Investigations	3	6%	24	53%	18	40%	0	0	45
Organize & Represent Data	2	4.5%	18	41%	23	52%	1	2%	44
Support claims with Evidence	8	18%	18	41%	18	41%	0	0	44
Determine data to be collected answer a scientific question	1	2%	14	31%	23	52%	6	14%	44
Analyze data	7	16%	19	43%	19	43%	1	2%	44
Develop Models		5%	16	36%	23	52%	3	7%	44
Use data and reasoning to defend/refute a claim	2	5%	6	14%	31	70%	3	7%	44

Students in the survey respondents' classes receive opportunities to conduct scientific investigations more than half the time during instruction, an encouraging sign considering that is the focus of the SSEC units. However, opportunities for students to engage in other practices seem to occur less often. Survey respondents reported that students' opportunities to generate scientific questions, organize and report data, develop models, use data to defend or refute scientific claims, and identify the strengths and limitations of a model occur less than half the time. For example, sixteen teachers reported that students have the opportunity to develop models more than half the time. In contrast, twenty-three reported students having that same opportunity less than half the time.

In some cases, the respondents were divided equally among the categories. For example, nineteen teachers categorized their students' opportunity to analyze data as more than half the time. At the same time, the same number reported that their students had this opportunity less than half the time. For this practice of analyzing data, seven teachers categorized their students' opportunities as all the time, and one teacher reported that no opportunity for students to analyze data occurred in their classroom.

The students' opportunity to support claims with evidence showed a similar trend. An equal number of respondents (18) categorized their students' opportunity to support claims with evidence as more than half the time as less than half the time. Eight teachers reported that students supported claims with evidence all the time, and no respondents said their students had no opportunity to engage in this practice.

In two areas of practice in particular, using data to defend or refute scientific claims and identifying the strengths and limitations of a scientific model, an overwhelming number of respondents (31) reported that their students engaged in these practices less than half the time.

Only six respondents reported that their students had the opportunity to engage in these practices more than half the time, and three reported no engagement with this practice.

The teacher manual also includes a lesson-by-lesson list of crosscutting concepts featured in the unit. Two of the seven crosscutting concepts listed in the standards are not featured in the fifth-grade unit. Some crosscutting concepts appear as focal concepts in lessons and take a supporting role in others (see Table 13).

Table 13

Focal and Supporting Crosscutting Concepts By Grade Level Unit

How to Provide Freshwater to Those in Need ? (Grade 5)	How can Animals Use Their Senses to Communicate? (Grade 4)
Focal Crosscutting Concepts	
Cause and Effect (13 Lessons)	Systems an System Models (8 Lessons)
Systems and System Models (5 Lessons)	Structure and Function (5 Lessons)
Structure and Function (2 Lessons)	Cause and Effect (5 Lessons)
Scale, Proportion, and Quantity (4 Lessons)	Patterns (3 Lessons)
Stability and Change (2 Lessons)	Scale, Proportion, and Quantity (2 Lessons)
Supporting Crosscutting Concepts	
Systems and System Models (3 Lessons)	Patterns (2 Lessons)
Scale, Proportion, and Quantity	
Not Featured in This Unit	
Patterns	Energy and Matter
Energy and Matter	Stability and Change

When a lesson is cut, the opportunities for students to employ the featured Practices and Crosscutting Concepts also diminish. The instructional materials are designed with all three dimensions in consideration. Therefore, it is a concern that teachers place so much emphasis on the disciplinary core ideas but not the other dimensions of the standards. This concern will be discussed further in the next chapter.

Electronic Supplemental Materials added to SSEC Modules

Teachers responded to questions regarding supplementing the SSEC units and the rationale behind their decisions. In one question, teachers noted how often they used online educational materials that were part of a subscription plan or paid for with personal funds. Of the 44 teachers who responded to this question in the survey, 24 noted that they use these materials in addition to the Smithsonian materials several times per month, and 11 respondents noted that they use them less than once a month. Five noted that they use these materials about once per month. Four teachers responded that they never use subscription materials or materials that they purchase with personal funds (see Table 14).

Many online resources are available to teachers, and often, districts carry an online subscription. Of these materials, BrainPop stood out as the most often used by the survey respondents, with fourteen mentions as the resource used most often. BrainPop is an online platform that offers short videos that cover a wide range of topics. The cartoon video characters give simplified explanations of topics in various subject areas, including science. Students watch the video; if desired, teachers can assign an online quiz on the video they have just seen. Some survey respondents reported using these quizzes to collect grades for their report cards.

Table 14

Survey Respondent Use of Subscription Websites to Supplement SSEC Materials

Frequency of Subscription Site Use	Number of Survey Respondents	Percent of Survey Respondents
Once a month	5	11.11%
Several times per month	24	53.33%
Less than once per month	11	24%
Never	5	11.11%

The website claims that the videos align with standards but does not clarify if this alignment is with the NGSS or a particular set of state standards. There is no opportunity for students to engage in any of the Science and Engineering Practices of the NGSS or the Crosscutting Concepts. Ultimately, the videos give simplified overviews of complex science topics.

The second most used website reported in the survey is Mystery Science, also known as Mystery Doug. The Mystery Doug/Mystery Science website features short weekly videos (less than ten minutes) based on students' questions posed on the site, MysteryScience.com. Questions such as, "What is the longest anyone has ever stayed awake?" and "How does Velcro work?" are examples of questions answered in these videos, which contain factual information in kid-friendly language. The videos are marketed as fun facts for curious kids and do not claim alignment with any standards.

The third most used supplemental material comes from Teachers Pay Teachers, a website where teachers create and post materials they have made. Offerings vary from units to holiday crafts to worksheets on any topic. One can purchase and download the materials for use in the classroom for a nominal fee. Materials offered for science sometimes claim to be aligned with standards. Still, anyone can put products on this site for sale, and there is no guarantee that the science content is accurate or aligned with any standards.

In her interview, Ann described supplementing her lessons with a ten-minute spiral review of material at the beginning of each lesson and adding supplemental academic vocabulary.

Ann noted:

> We have to supplement a little bit, mostly in vocabulary because the vocabulary is good for the particular units, but as far as like overall science vocabulary in that spiral, it doesn't really exist in the units, at least not from what I've seen.

Ann described a science vocabulary series that her district used previously but has since discontinued. However, she and her colleagues noticed a difference in her students' ability to talk about scientific topics without the series, so they have reinstated it for the upcoming school year. She will spend about five or ten minutes doing a short lesson each day at the beginning of the science class, following the lesson order in the series, and teaching the SSEC vocabulary separately.

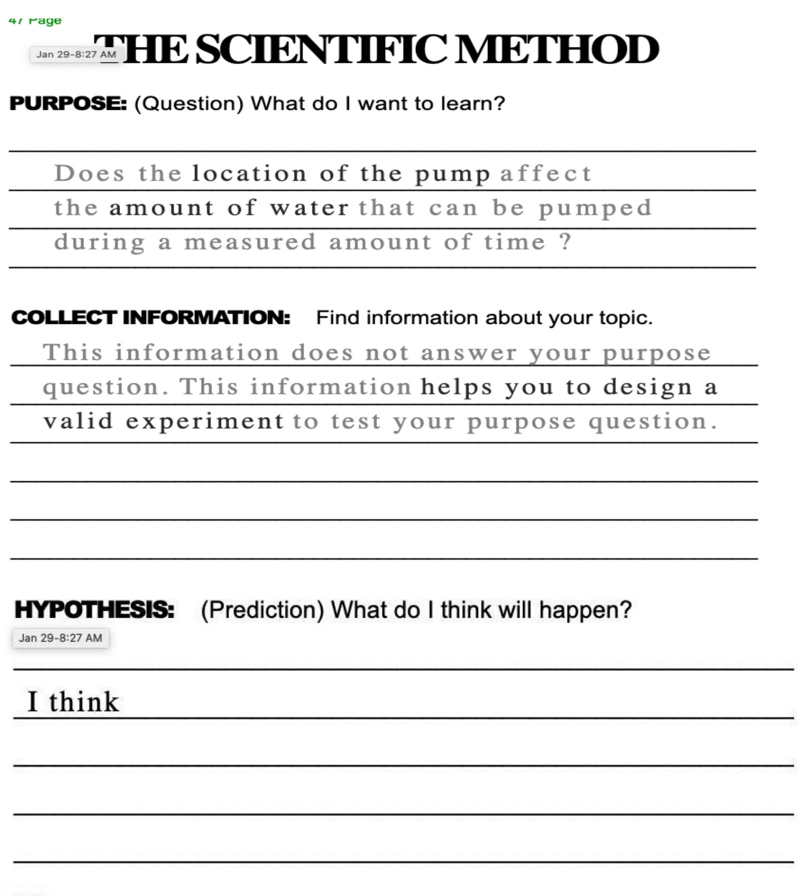
Ann notes that just general science vocabulary is what she wants her students to know, along with the scientific method:

> So like the scientific method, for example, is something that kids should know about and they should know the steps, and it might be taught or mentioned throughout different parts of the unit. But as a k-5, it's not something, there aren't particular vocabulary words that are spiraled all the way through.

Ann does not appear to realize that the Framework and subsequent NGSS deemphasize teaching the scientific method and teaching vocabulary in isolation. However, Ann was one of several teachers to mention the need to teach children the steps of the scientific method. Carl, Jack, and Ireland also mentioned that the SSEC does not emphasize the scientific method but should. Of those who mentioned the need for the units to include the scientific method, Carl was the only interviewee who noted that he takes the time to teach the scientific method to his students. An example of how he incorporated the scientific method into the fifth-grade unit appears in Figure 4.3.

Figure 4.3

Sample Scientific Method Lesson Work Page



47 Page

Jan 29-8:27 AM

THE SCIENTIFIC METHOD

PURPOSE: (Question) What do I want to learn?

Does the location of the pump affect the amount of water that can be pumped during a measured amount of time ?

COLLECT INFORMATION: Find information about your topic.

This information does not answer your purpose question. This information helps you to design a valid experiment to test your purpose question.

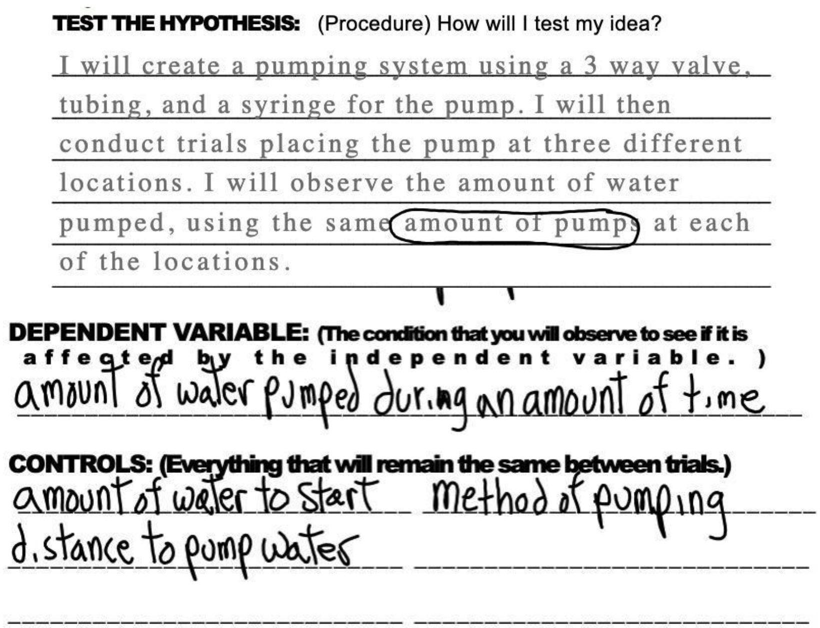
HYPOTHESIS: (Prediction) What do I think will happen?

Jan 29-8:27 AM

I think

48 Page

Figure 4.3 (Continued)



TEST THE HYPOTHESIS: (Procedure) How will I test my idea?

I will create a pumping system using a 3 way valve, tubing, and a syringe for the pump. I will then conduct trials placing the pump at three different locations. I will observe the amount of water pumped, using the same amount of pumps at each of the locations.

DEPENDENT VARIABLE: (The condition that you will observe to see if it is affected by the independent variable.)

amount of water pumped during an amount of time

CONTROLS: (Everything that will remain the same between trials.)

amount of water to start

method of pumping

distance to pump water

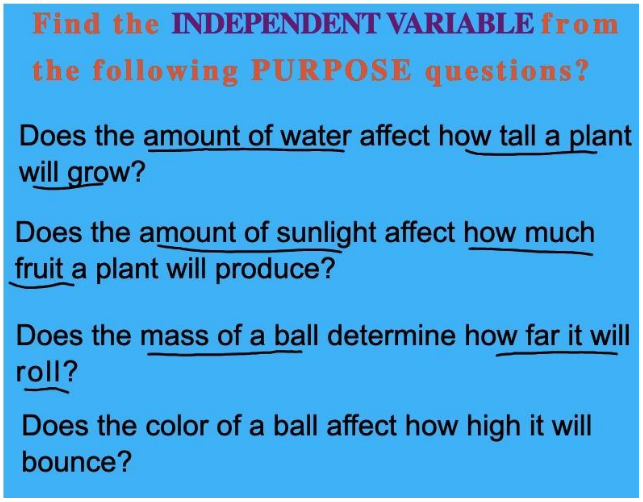
Carl shared:

> I start out the year, the first few weeks of school before we even get into them with a unit on the scientific method, how to conduct experiments and the variables and things like that because most of these units are using that process.

As part of the direct instruction about how to write up an investigation using the scientific method, Carl also provides instruction and practice for students regarding identifying independent and dependent variables and using controls (see figure 4.4).

Figure 4.4

Sample Teacher-Led Variable Identification Lesson Slide



The Next Generation Science Standards support a shift from the idea that scientists use a particular scientific method to conduct their work. The scientific practices that scientists use are incorporated into the NGSS to allow students to emulate the many methods scientists employ to conduct their work.

The Framework explicitly challenges teaching the scientific method as a misrepresentation of how scientific knowledge is generated:

> A focus on practices (in the plural) avoids the mistaken impression that there is one distinctive approach common to all science—a single "scientific method"—or that uncertainty is a universal attribute of science. In reality, practicing scientists employ a broad spectrum of methods, and although science involves many areas of uncertainty as knowledge is developed, there are now many aspects of scientific knowledge that are so well established as to be unquestioned foundations of the culture and its technologies (NAP, 2012, p. 44).

Carl and his colleagues from the study appear to be unfamiliar with this intentional move noted in both the Framework and the NGSS, nor does the instruction of the scientific method appear as part of any standard in the NGSS.

Jack also noted that he supplements the units with other information that he feels is helpful for students to know. Jack gave the following as an example of what type of information he adds to a unit related to a different fifth-grade unit: *How Can We Use the Sky to Navigate?* Jack stated:

> So, for example, when we were going through the stars and the constellations, pretty much every kid in my class can tell you that the speed of light is 186,000 miles per second, that we spin at the equator at a thousand miles an hour. And then we took it even bigger. We went into the solar system, and they can tell you how fast the Milky Way is spinning and how fast…."

Jack noted later in the interview that he sometimes uses some high school material. It is noteworthy that the material noted above is not aligned with any fifth-grade standard and is not introduced until eighth grade for good reason. Before students can understand the ideas Jack presents to his class, they need to learn more advanced concepts of scale, proportion, quantity, and ratios than they have by fifth grade. Therefore, Jack's students may be able to repeat the fact, but they likely do not truly understand the meaning. Further, the accumulation of facts without truly understanding the science behind those facts is what the Framework and the NGSS are trying to discourage.

Jack and Carl also noted that they provide other supplemental material to the units. For example, Carl shared::

> Most kits I start out with some of my own content material because I like these kits. I think they're good. They promote investigations and things like that with the students and they have some pretty good investigations. The thing I find the most fault with them is they're very light on content. I have pretty much made my own little lessons and supplements to each of these units.

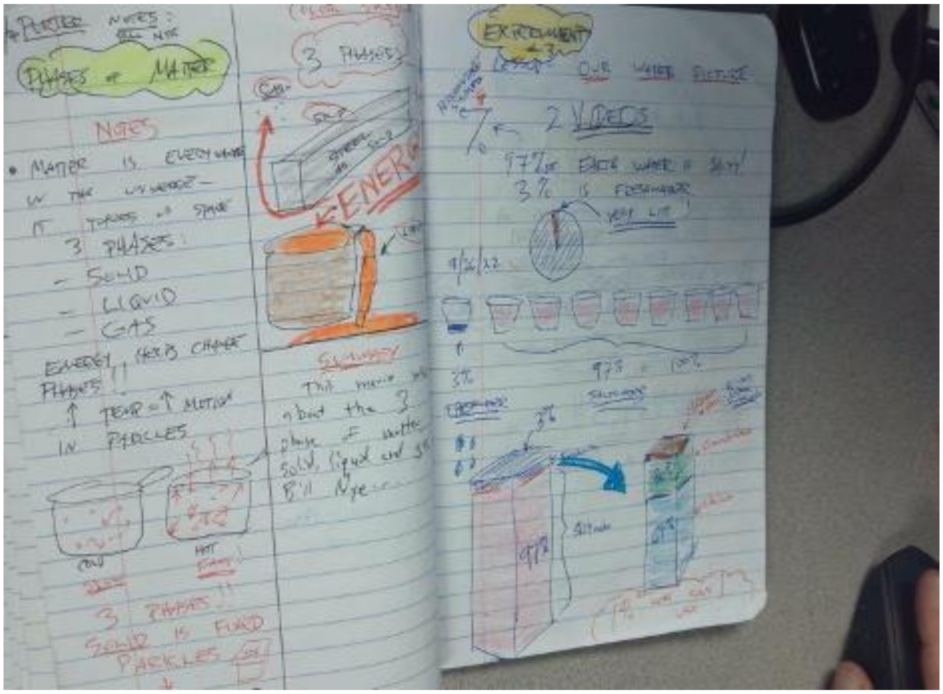
It is interesting that Carl feels the need to take away some portions of lessons but feels it is necessary to add content. For example, in a lesson, students work in small groups and study the criteria, constraints, and materials to design and test a system that moves water horizontally using a syringe, tubing, and a three-way valve. They discuss the system's success or lack thereof and collaborate on improvements, which they then redraw, build, and test. Once students have tested their initial and subsequent improved design, the teacher's manual directs students to form new groups composed of one member from each original group. In this new group setting, students describe their designs, show drawings, and discuss the level of success. Eventually, students rejoin their original group and share what they learned from their peers. Lastly, the whole group comes together to discuss what went well and what changes to their designs students would like to make going forward. This collaborative exercise represents the engineering design process, an important update to the NGSS relative to previous standards.

Carl's slide deck indicates that the students in his class do not meet with other group members, share new information with their original group members, or participate in a whole group wrap-up discussion. Instead, Carl's lesson concludes with direct instruction about watersheds, aquifers, and the water cycle, accompanied by maps of water drainage basins in the US, diagrams of aquifers, and a note sheet on which students write the information. That note sheet becomes a study guide for a quiz on the material later in the unit. This depth of exploration of these ideas is not part of the fifth grade NGSS but is assigned to middle school standards. However, Carl does not appear to realize this and feels the need to provide additional content at this level. What is also noteworthy is Carl's more traditional approach to teaching science; substituting direct instruction in the form of disseminating facts for student collaboration and model sharing.

During the interview, Jack also noted that he adds content to every lesson and pulls content-related materials from the Internet. He stated that the Smithsonian materials are the best he has ever worked with, but he feels he can add more to the students' understanding of the topics. Jack created a note system, an adapted version of the Cornell notetaking system, invented in the 1950s. In the Cornell system and Jack's adapted system, students draw a line down the center of a note page, scribe the required notes on the left-hand side of the center line, and on the right, draw diagrams and write keywords and questions. A sample of a note page from Jack's notebook appears in Figure 4.5.
Jack explained:

> I created my own note system. I call it [Teacher Name] notes. And I do a little line down the middle of the paper. That's your notes. And then I divide it again off to the right, making a sideways T, and the upper right section is a scientific sketch with arrows and labels, and down below is a summary. So every one of my lessons we what I call [Teacher Name] notes. You have notes, you have a scientific sketch, and you have another section with a summary.

Figure 4.5 *Sample Teacher-Created Supplemental Note Sheet*



The above figure exemplifies what Jack feels is essential for his students to know. The page on the left shows notes taken from a Bill Nye video about changes in the states of matter, while the notes on the right are notes from two supplemental videos and what appear to be some drawings related to Lesson Three in the unit. Jack noted that he often uses this note system instead of the sheets provided in the instructional materials, despite saying earlier that he uses every resource that comes with each lesson.

Jack and Carl rely on other sources to explain to students instead of offering students opportunities to build explanations themselves. From the examples above, one can see distinct diversions from the SSEC-provided lessons. Jack and Carl may need to understand better that the focus of the standards and, by extension, the SSEC unit lessons is for more than just students to learn content. Recall that they both claimed not to skip lessons earlier in their interviews. However, by changing the lessons to be more teacher-led, they are eliminating some objectives of the lessons when they seem to think they are meeting the lesson's goals, just in a different way.

Modifications to the Materials

Two types of changes to the SSEC materials were prevalent in the survey results and interviews: those made to the physical materials and those to the lesson procedures themselves. The previous sections have outlined how teachers have skipped full or partial lessons and have supplemented the lessons; this section will focus on substitutions made during the lessons and how teachers have modified materials, namely the work pages.

When asked how they used the SSEC materials, 30.95% of survey respondents noted that they modify them consistently, and 61.9% said they modify them occasionally. Interview participants cited work pages as the most often modified material. Teachers talked about altering the size of the space provided for students to write in, creating more precise directions, cutting down on the number of questions on the work pages, and adding sentence starters for students to use.

Katie noted that as a teacher in a co-teach classroom, she was mindful that many of her students had issues with handwriting, and the work pages, in their half-sheet format, provided insufficient space on the page for her students to write their responses.

She said:

> As time has gone by, I can only speak for myself with this, I was much more selective on what ones [work pages] I did use and what ones we just maybe had them write a sentence on or what ones I maybe just filled in myself on the Elmo.

When discussing the work pages she did use, Katie added:

> I would take one and blow it up to a full sheet. Other times, I would modify it myself and maybe the half sheet would have like five boxes, with all T-charts. Well, I would make it where let's split your paper in half and do two T-charts up top, two T-charts on the bottom, and do it that way.

Carl also feels his students cannot manage the work pages as they are produced. He described what he has done to make the work pages work for his students:

> One of the major modifications for these kids is their [Smithsonian] workbook note pages. They give you a little box and the kids are supposed to write an explanation. Our kids can't do that. They need lines and they need more than a little box. So I remake every single note page. I have rebuilt every single note page as a full-size page and it gives them lines and it gives them much more space to write their ideas out and things like that.

Another teacher, Maya, described her desire to keep the hands-on investigations.
designed because her students enjoy them, and she feels they learn best by getting to do the work themselves. However, she does not always use the work pages that go along with theinvestigations, at least not as designed.

She explained:

> I used interactive notebooks, so there were times when I just had them write down about the lab and respond to the lab. There were times when I photocopied the data sheets supplied by the Smithsonian, and they glued them in and took the lab materials that way. And then there were times where, what the worksheet provided, it wasn't totally aligned with our state standards, so I would have to tweak it.

It’s important to note that it’s possible that Maya’s state standards aren’t aligned with the NGSS and the “tweaks” she mentioned were to make NGSS-aligned materials more compatible with the standards she is required to teach.

Research Question 3: What rationales do teachers present for these modifications?

The teachers who participated in this study have provided insight into their decisions when planning and teaching science to their elementary students. This section provides data from both the survey and interviews that illuminate the rationales behind those decisions.

Time

The most common theme from the survey and the interviewees combined was that time was the primary factor influencing changes to the SSEC materials during planning and instruction. Thirty-six of the 45 respondents who answered the question noted that they either skipped something in the SSEC materials because they needed more time to teach the lessons as written or had to skip entire lessons when they ran out of time. Thirty-three of 42 survey respondents noted that they also modified materials due to time constraints.

Recall that there are four fourth grade and four fifth-grade units in SSEC. Each fourth-grade unit is designed for 20 class periods of 40 minutes each. In total, 800 minutes of class time is required to complete each unit. Therefore, 3200 minutes of class time is required to teach all four units, presuming that the time allocations within the teacher guide are reasonable. Three fifth-grade units are designed for 20 class periods; one is designed for 21, all 40 minutes long, requiring 800 or 840 minutes per unit. To complete all four units, 3240 minutes of class time is required. This total time estimate became the baseline against which I compared the teachers’ time-related responses in the survey.

To determine how many total minutes the survey respondents spent science teaching, I analyzed teachers' responses to survey questions asking them to report the minutes per day, days per week, and weeks per year spent teaching science. I kept the wording of the survey questions consistent with the original survey, which asked respondents to select a range of time most closely aligned with their classroom teaching. Thus, to analyze this data, I calculated the minimum and maximum number of minutes per year that would be possible across their answers. As shown in the figure below, if a teacher reported teaching science for 30-45 minutes per day, 2-3 days per week, for 31-40 weeks per year, this yields a range of total minutes between 1860 and 5400, a significant difference. (see Table 15)

Table 15

Example Comparison Calculations for Minutes Reported to Complete SSEC Unit

	Range of minutes per lesson	Range of lessons per week	Range of weeks per year devoted to science teaching	Total Number of minutes teachers report teaching science
	30-45	2-3	31-40	
Number of minutes required for the year using high numbers	45	3	40	5400 minutes
Number of minutes required for the year using low numbers	30	2	31	1860 minutes

If the fourth-grade teacher in the above example taught all four units, the SSEC expects her to spend 3200 instructional minutes teaching science across the year. Using the high numbers in the above ranges, this teacher could spend 5400 minutes to complete all four units, well over the 3200 minutes described in the SSEC materials. However, if the teaching time is closer to the lower end of the ranges, this teacher only has enough minutes to finish two feasibly or, to address the content in all four units, would have to skip at least half of the lessons in each of the four units.

Fifty teachers answered all three questions about the number of days per week, weeks per year, and minutes per lesson they spent teaching science, and 37 of these also responded that they had either skipped or modified lessons due to lack of time. I used the calculations described above to compare the number of teaching minutes reported by respondents to the number of minutes required to teach the modules according to the teacher guide.

Of the 37 teachers who reported a lack of time to teach the units as designed, three respondents' answers indicate that they do not have the required number of minutes to complete the units as directed by the SSEC materials in either the high or low range. Fourteen teachers' responses indicate enough minutes to teach the modules as designed if the number of minutes they teach science is at the high end of the range but indicate a deficit of available minutes in the low range. However, 20 respondents report teaching science where the high and low ranges of their answers exceed the 3200 minutes needed to implement the SSEC materials as designed fully. The claim that there is not enough time to teach all lessons in the unit does not match up with the designated amount of time prescribed by the SSEC materials in many cases.

I analyzed the survey data to compare the amount of teacher control over instructional time for science teaching among survey respondents to those who reported skipping or modifying lessons. Table 16 depicts the amount of control over science teaching time reported by the fifty-one respondents who answered the question. Ten reported having a great deal of control, 18 reported a moderate amount of control, 16 reported little control, and seven reported no control. Interestingly, of the ten who reported having a great deal of control over how much time they spent teaching science, only three reported skipping or modifying lessons due to lack of time. Similarly, of the 18 who reported moderate control, only eight reported skipping or modifying lessons due to lack of time.

Table 16

Survey Respondent Control of Instructional Time for Science Instruction

Great Deal of Control	Moderate Control	Little Control	No Control
10	18	16	7

Conversely, of 16 teachers who reported having little control over how much time they spent teaching science, 14 reported skipping and modifying lessons due to lack of time. Two reported omitting lessons but did not report making any modifications to the lessons they did teach. Six of the seven teachers who reported having no control over how much time they devoted to science teaching reported skipping and modifying lessons due to lack of time. The percentage of those with at least moderate control over their instructional time for science, and the percentage of those reporting little or no control, 54% and 46% respectively are close to the same. More significant, however, is that 91% of those with little or no control over their science teaching time report changing and skipping lessons due to lack of time, compared to 40% of teachers who report having at least a moderate amount of control. These results suggest that the less control the teachers have, the more likely they are to skip or modify the SSEC materials, creating a situation that could negatively influence student learning outcomes.

Interview participants cited time as a significant factor in determining what gets taught during science time and how it gets taught. Three interviewees teach science for 60 minutes every other day, six for 30-45 minutes every other day, and two teach science every day for 45 minutes. Only one of the interviewees teaches for 60 minutes per day all year. All but four also teach social studies either in five-week blocks that rotate with science or rotate social studies with science every other day. The number of minutes teachers teach science is only a portion of the time teachers have to devote to science instruction, however. Two science-related themes became evident during the interviews: the time it takes to prepare the materials and the time the lessons take to execute. These two themes explain why teachers skip or modify materials.

Several respondents noted that the preparation of materials is very time-consuming. For example, Katie noted:

> They are extremely time-consuming, time-consuming in setting up and time-consuming in having the children do it. And elementary teachers are only given one chunk of prep time. And there are times that the hands-on portion of the kits could take up one or more of our planning times just to set it up, which is upsetting because some of the stuff is really good. It just is at times not realistic in what we're able to adequately do and keep our sanity.

Laura gave a similar account of how the preparation of the materials impacts her instruction:

> I would say [I'll skip] the ones that require so much prep time, or prep, like whether it's setting up bins with all the materials and just that time-consuming prep. Those ones I'm going to probably shy away from just because I personally don't have the time to prep it all. When I cut, it's usually those intensive preparation ones.

Izza also described dropping some lessons because of the amount of preparation involved:

> Some of the fireflies activities at the end, we decided to pull because of setup. So what we found with some of the units, and not just this particular unit, but just our science units in general, start to be a lot of setup to drive home a point that we found they might already understand, or that they could get in a different way or that we might just be able to talk about.

In addition to time for preparation of materials, interviewees noted that they make modifications because the lessons take much longer in the classroom than the teacher guide reflects. Ireland provided insight into how she and her colleagues manage the lesson timing in her building. "So we see one Smithsonian class period as two class periods for us. If it is a hands-on lesson, I change it to three. That is our hard and fast."

Katie also noted that she could not use the suggested lesson time from the teacher guide.

> I find that these suggested times for each lesson are vastly under what it really takes to do a lesson. So the teacher manual may say that this particular lesson will take two sessions of 40 minutes when in actuality, I found that sometimes those lessons could be four days of 40 minutes each. And that in turn makes us have to go through and pick and choose what lessons we feel we can do, and what lessons we feel are most important for the students to have experience with.

Perceptions of Student Ability

Although lack of time was the most prevalent reason for skipping or modifying lessons, it was not the only reason. Fourteen survey participants cited the SSEC lessons as too difficult for their particular class and, similarly, that the lessons did not meet the needs of students, so activities had to be changed or skipped to provide for different levels of achievement among their students. Interviewees also noted skipping SSEC lessons or activities within lessons for these reasons. Katie has many years of experience as a teacher in a co-teaching class. During her interview, she acknowledged that her students might not represent the typical SSEC users, but she sees the need to skip, substitute, or modify the materials. When talking about an activity in the module *How Do Animals Use Their Senses to Communicate?*, she said:

> To be honest, if I felt the lesson, even if it was supposed to be hands-on, was going to be over their heads, too complicated or boring, I would find something else. I know the standards have changed, but I know what types of lessons will make them understand the animals, needing to know that they have different size corneas that let them see different things.

This statement indicates that Katie focuses on ensuring students know which animals have what size corneas. But this knowledge alone is not really the point of the unit. The unit focus is not for students to know these facts specifically but to understand that an animal's structure relates directly to how it functions in its environment. The relationship between structure and function is a key Crosscutting Concept featured in the unit. Katie's statement infers that she is conscientious about making sure the students understand what she perceives to be the focus of the lessons. However, her perception is, at best, incomplete.

Maya also noted, "There were, I would say, a few lessons, maybe three lessons out of both kits that I thought were overwhelming for students that I did tweak it for them."

Shelley, likewise, has made modifications based on what she perceived as too difficult for her students. "A lot of times, the students, if they are not ready to do claims and evidence, we might have to skip over that if they are not there yet. It really just depends on the makeup of your class." Shelley did not mention if there are classes that she feels are never ready for claims and evidence, and, therefore, the students never get opportunities to try those practices. She also did not mention that she is concerned if other teachers have the same sentiment about the same students, who then do not practice these skills in subsequent years either.

Teacher Confidence

Four survey respondents noted that they made changes to the SSEC materials because they lacked the knowledge required to teach the lessons as written, and one interviewee, Molly, was especially candid about her lack of confidence and how that impacts her students. Earlier in the interview, she explained that she works hard to try and make up for her lack of knowledge and she explains that her team has a science "guru" who does most of the unit planning and prepping for which she is grateful, but sometimes that is just not enough.

Molly explained:

> Science had the least amount of time when I was a kid. I remember a lot of lectures on science throughout my childhood and high school experience, and I wouldn't be surprised if that helped me develop sort of a dislike for the subject or at least a lack of understanding. I do my best. I just think that my lack of comfort and knowledge does come across at times to kids, and for that, I feel incredibly guilty. I know that when I

> can't understand it, I can't teach it. I just may present it and move on or I may just skip it altogether.

Another teacher, Laura, also explained that there are parts of the modules for which she has to seek help from colleagues.

She explains her lack of confidence with some of the material:

> Science wasn't a subject that I excelled in. It was just always something that I struggled academically, personally, with. I struggle with the electricity one [module]. If it's something that I truly had no idea with, I'm sure one of my co-workers could help me figure it out, but- so for the electricity one, I do use some of the former kit lessons for some things. Sometimes we read things, and I'm like, 'I don't really know the answers to this guys.' I would say they [the Smithsonian] did a nice job putting the background information in the teacher guide, but sometimes it's not quite enough.

The key to good instruction in any subject is knowing the material well. As these two teachers have explained, not feeling comfortable with the science material can strain a teacher with so much on their plate.

Shelley feels confident in her own science teaching ability, but does note that science is a stressor for her colleagues:

> I think science is a really big stressor for a lot of teachers and the teachers that I work with in particular, when they have to talk about science, they have a big sigh because it is a lot. There are a lot of materials, a lot of setup and a lot of really intense thinking in all aspects of it. I think a lot of teachers have a lot of apprehension about it because it is complicated. And I think it's [teaching science] just not as innate in people as math and

> ELA. I'm happy to assist. I love science. It's my passion, but I think if they're going to skip something, I think a lot of teachers would skip it.

It is not difficult to imagine that with so much on their plates, teachers who do not understand the material as exemplified in the interview statements above, would be hard-pressed to find the time to be able to study a concept they do not understand themselves and still have time to prepare materials for classroom instruction.

Summary

The Horizon Research Corporation Study, the 2018 NSSME+, on which the survey questions in this study and subsequent interview questions are based, provided broad evidence that teachers change science instructional materials but did not investigate a single title or "brand." This study allowed for a detailed analysis of teachers' answers about one published set of instructional materials designed to align with the NGSS. Understanding the changes and why and how teachers make them in their day-to-day work with students is essential if we are to know what teachers need to successfully implement the standards as intended. The focus of this study was to provide specific examples of what changes teachers made to the instructional materials and determine how they made the decisions to change the materials and the rationales used to justify the changes. This study investigated three research questions to analyze these interactions with science materials.

The first research question focused on how teachers approach the unit as a whole and then lessons individually. Interview responses were the primary source of information for this question. This question was important because initial decisions about how to teach the unit influence what instructional materials from the modules will be used during instruction. Students in a particular grade level would likely receive similar instruction if decisions about approaching the unit resulted from a group decision made by grade-level teachers. In contrast, teachers who approach the unit individually increase the likelihood that students in one classroom could receive instruction quite differently from others in the same grade level in the same school. Further, the primary purpose of this question was to provide a sense of the timelines for when teachers made the decisions regarding changes to the materials.

The second question focused on teachers' specific changes to the instructional materials. Going into the study, I believed that teachers in this study would cite the elimination of lessons or portions of lessons to be the most common change made to the materials. The results of the 2018 NSSME+ and personal experience suggested that I would likely find that teachers made more cuts to lessons than other modifications, such as adding materials. While the study did show that teachers supplement materials more than I conjectured, far more respondents cut material from the units than made additions.

The third question focused on the rationales teachers provide for why they make the modifications they do. Relevant literature noted that many districts across America focus on mathematics and ELA, the subjects primarily tested nationwide. This focus and adherence to local and state mandates make finding time to teach science difficult for elementary teachers. Based on this and personal experience, I surmised that the study would confirm that the primary reason for modifying the instructional materials would be time constraints. The participant responses confirmed this conjecture. Feeling that the students were not ready for the challenging content in the lessons as well as a lack of confidence in their own ability to teach the material adequately were also moted as rationales for making changes to the material.

Chapter Five: Discussion

The findings discussed in Chapter Four provide insights into how teachers prepare and deliver science instruction in elementary classrooms. Many teachers in the study cited challenges they face when planning and delivering science lessons, even when the materials for those lessons are supplied in a published curriculum. Time constraints for preparation and lesson delivery, emphasis on other disciplines such as math and ELA, and interruptions in instructional time impact how teachers can teach science and force teachers to make instructional decisions based on these factors. This chapter explores the implications of these findings for teachers, administrators, professional development providers, and curriculum developers. Further, this chapter summarizes each research question, cites the study's limitations, and provides suggestions for future research.

When commercially published science modules contain all materials required for teachers and students to complete a unit of study, including hands-on materials, guides for investigations, and teacher materials physically in one place, science in the elementary grades theoretically becomes more manageable for the teacher to plan and implement. High-quality instructional materials aligned to the latest standards, the NGSS, or a state's adapted version, provide the best opportunity for all students to receive quality science instruction. As a complete module, the chances increase that students will be able to engage in the investigations described in the unit as directed because all appropriate resources appear in the crate. Now that the standards are a decade old, more research about the NGSS is available. Metrics do exist that districts can use to evaluate how well materials align with the NGSS or state standards based on the NGSS that aid in the adoption decision-making process. Undoubtedly, districts take this decision seriously, given the expense of the modules to purchase from distributors or rent from a regional science center and the desire of the district to afford its students the best possible science education, but how districts represented in this study decided to adopt the SSEC materials for use in elementary classrooms is beyond the scope of this study. The day-to-day use of the instructional materials is relegated to the classroom teacher, who then determines how best to use them for instruction. Ideally, these materials will be used as indicated by the developers, as that is why the district chose those materials in the first place.

The overall goal of this study was to provide classroom-level information about how teachers use the materials, how teachers make decisions about the materials, what changes to the materials teachers make, and why they make them. Data collected during the survey provided general information about units taught, experience with the SSEC materials, and teaching in general. Patterns and trends emerged from the data in the survey that informed the questions asked in the interviews and provided a pathway to interrogate specific classroom-level practices by individual teachers.

The standards promote science learning as engaging in the work of scientists and engineers instead of following a linear pattern of steps, promoting depth of science content over breadth, and realizing that the same science concepts are relevant over different contexts. Units like the SSEC, designed to align with the standards, reflect these ideas.

Carl and Jack believe adding more scientific facts is warranted due to the “lack of content” in the units. This thinking provides evidence of their misunderstanding that disseminating facts, especially factual material that is not grade-level appropriate, does not equate to student learning or understanding, nor does it allow students to develop the skills to use as citizens, such as recognizing when public information is science-based and when it is not. Further, Ireland and Jack noted that they felt that the “Scientific Method” should be included in the science lessons, once again showing that they have not had an opportunity to learn that this is a deliberate omission in the NGSS. This omission encourages students to revise their thinking as new knowledge is acquired instead of thinking that it cannot be revisited once one “step” of the investigation is complete.

Despite some evidence that teachers may not yet fully understand the nuances of the NGSS or how the SSEC materials align with those standards, it is clear that those interviewed were trying to do their best to attend to student needs and adhere to the standards as they understood them. Some teachers who were interviewed expressed frustration at the constraints of time for preparation and delivery of lessons, and the demands on their time that create those constraints.

Limitations of the Study

Several limitations impact the generalizability of the results of this study. The first comes from my role as a researcher in a field with which I have experience teaching and learning elementary science in general and teaching and learning with the SSEC materials specifically. My beliefs on what constitutes good teaching in elementary science could influence how I conducted interviews and coded responses. Because of my familiarity with the SSEC instructional materials from my previous teaching position as a science lab instructor and science coach, it was easy to put myself in the participants' position and connect with them because we had similar teaching experiences. Personal experience with three interviewees as a former colleague and science coach and experience teaching elementary science to children in grades K-6 were areas that could give rise to investigator bias. Being highly cognizant of that during the interview and the coding process was essential. Reading numerous articles regarding survey and interview protocols and limitations helped me to focus on remaining a neutral interviewer, as did my advisor.

A second limitation lies in the survey sample. The survey was sent to 1354 Smithsonian Science for the Classroom users as defined by the financial information obtained from the distributor. However, these recipients were only those whose emails were made public. Teachers in districts included in the list as having adopted the SSEC materials district-wide but did not make teachers' emails accessible to the public could not be contacted. Therefore, it is impossible to know if the responses from those who were unreachable would be the same as those who were. Further, it is possible that the interviewees agreed to an interview because they had strong views on the instructional materials or elementary science. Their views may not be representative of their peers.

A third limitation of the survey arises from the survey's low response rate. Of the 1,354 surveys mailed to teachers nationwide, 47 were returned as undeliverable, leaving a total of 1,307 that were delivered to emails across the country. Of those, 57 teachers sent responses, representing only four percent of all teachers surveyed, a percentage too small for generalizability. It is also possible that those who answered the survey questions did so because they had specific and strong feelings about teaching science with the studied instructional materials and, therefore, affected response bias.

The timing of the surveys likely played a role in the low response rate as well. The survey reached teachers on June 6th and 7th of 2022. In the Northeast United States, schools had another two weeks of school left, whereas, in the Midwest, West, and South, schools were in their last few days of the school year, or the school year had just ended. End-of-year activities and teacher responsibilities may have contributed to the lack of response. Another possible reason for the low response rate might have been teacher fatigue. The survey was issued at the end of the first full school year after the COVID-19 pandemic. COVID has been linked to teacher burnout which may have affected the response rate. While not generalizable, the responses from the survey and the interviews serve as food for thought and topics for future research.

I believe that my position as a novice researcher also proved to be a limitation in this study as, in hindsight, I would have asked some additional questions of the survey respondents and interviewees regarding how frequently students engaged in the crosscutting concepts of the NGSS as I did the scientific and engineering practices. Because the standards are three-dimensional, giving all three dimensions the same amount of attention in the survey would have been helpful. Attention to the crosscutting concepts would then have also impacted the interview questions I asked as I drew those questions from responses received from the survey.

All interviewees answered the questions on the survey and agreed to be interviewed voluntarily. Of the 57 who responded to the survey, seventeen agreed to be contacted for an interview, but only twelve (21%) responded to requests to schedule a talk. This low response rate suggests that, like the survey, the responses cannot be generalized but can be used to indicate areas where further study is warranted.

Whenever study participants self-report, there is a risk that what they report is an interpretation based on the participant's belief system. In a survey, the participant does not have the opportunity for clarification of a question. In an interview, there is always the potential for respondents to remember events or actions differently than they occurred or forget specific facts that would alter their responses. There is also the potential that the respondents may try to answer in such a way as to look more positively to the interviewer.

While the interviewees were from different parts of the country, they overwhelmingly represented rural and suburban schools. One interviewee said he taught in an urban district, but his school was the most "suburban" of the entire district, and it serviced a more suburban population than some of the other schools. Another area that had implications for generalizability was that all interviewees were white. Therefore, this study did not include personal perspectives about the SSEC materials from People of Color.

Because the interviews were conducted by phone, this researcher could not see facial expressions or body language. When reviewing the confidentiality and privacy protocols with participants before our conversations, they sounded comfortable, seemed to speak freely, and were forthcoming with information. However, two participants did begin a statement during the interview with the words, "I probably should not say this," giving the impression that their statements might get them in trouble with administrators. At that time, they were reminded that their responses were confidential.

All of these limitations impact the generalizability of the study. However, the study's findings still suggest the need for further studies targeting a broader and more diverse population of elementary science teachers.

Implications of the Study

This study illuminates several implications for various stakeholders such as teachers, school leaders, professional developers, and further research, and notes where further research is warranted. A table summarizes specific concerns for stakeholders, followed by an explanation of each.

The teachers who took part in this survey took their time and energy to answer the survey questions, and the twelve interviewees agreed to an interview at one of the busiest times of the school calendar, the end of the school year. While only explicitly mentioned by a few interviewees, one can surmise that the teachers participated because they were eager to discuss teaching science and teaching with the SSEC materials. The interviewees were able to express their frustration with working with materials they felt were of high quality but, in many instances, set a standard that was beyond their reach to teach or the student's ability to successfully learn. Time to prepare the materials and teach the lessons was the constant obstacle noted in the study. Since teachers are the "front line" of any new reform effort or new curriculum implementation, it is imperative to understand what teachers know and understand to be the goals of the standards and the instructional materials and how these intersect. This small study indicates that teachers have not all had the same opportunities to learn about the goals of the NGSS. Further, the study also indicates that some teachers have yet to have an opportunity to understand how teaching with the SSEC instructional materials is deliberately different from teaching in traditional ways. Thus, teachers try to fit teaching with the SSEC materials into older teaching strategies that no longer apply.

Professional development (PD) is integral to any new initiative in a district. Most participants received PD on the modules from a regional trainer, but some trained themselves or with colleagues. The variation in training opportunities is an area that could impact instruction and the use of materials. Those who teach themselves have only their personal interpretations of the instructional materials to guide them, and it can be challenging to identify and change misconceptions when working alone, suggesting that science education from one class to another could be quite different. Another indication from the study that professional development can address is the mindset of teachers who receive the training. Understanding teachers' sociocultural influences and beliefs about teaching science along with what constitutes good science teaching is paramount to understanding how they interpret the standards. Providing intentional opportunities for teachers to see the differences between traditional teaching strategies, such as giving teacher-led lessons where students acquire scientific facts and teaching the NGSS, can provide insight into the pedagogical shifts that come with the NGSS as well. Walking through the unit lessons, often where professional developers place the emphasis, is productive. Still, more insight into the standards may be required to change a teaching mindset. PD providers may talk about the differences between traditional science teaching and using NGSS-aligned materials. As noted earlier in the chapter, despite professional development opportunities, teachers in this study attend to the factual component of the standards at the expense of the practices and crosscutting concepts, implying that a stronger emphasis on how and where the materials emphasize different standards' components warrants a closer look during module training.

While this study did not include materials developers, the results provide a strong message about time that is important for developers to know. Most changes to instructional materials, particularly where cutting lessons was concerned, resulted from time constraints. Whether these constraints are real or perceived is another area that warrants a closer look, but this study implies that teachers are not cutting materials uniformly. Developers need to know that this is a widespread issue for teachers and suggest what to eliminate or substitute if teachers do not have enough minutes to complete the lessons as written. This allows teachers to take advantage of the expertise of those with experience in curriculum writing instead of making cuts that may cause students to miss vital learning experiences. An area where this seems crucial is the culminating event. In each unit, the culminating event allows students to engage in all the SEPs, DCIs, and CCCs on which the unit focuses. Many teachers noted that they skipped these lessons due to time or setup constraints. Developers may offer shorter alternative lessons to teachers who do not have enough minutes to teach the lessons as written, thus allowing teachers to get to the culminating summative investigations. Results from this study may inspire changes to lessons in newer editions of the SSEC materials, or at least a closer look at the lessons already developed.

Many of the issues teachers in this study cited dealt with things beyond their control. The emphasis on ELA and mathematics, the tested subjects often tied to financial incentives for good scores, create classroom situations that force teachers to make difficult choices about instruction, especially in science and social studies. This study indicates that changes in policy at both the school and state levels could provide opportunities for more effective science instruction.

Table 17

Summary of Implications of This Study

Implications for Future Research
Need to identify how teachers understand the standards with special attention to the importance of the interwoven aspect of the Disciplinary Core Ideas, the Science and Engineering Practices, and the Crosscutting Concepts
Need a broader study of how time is being spent teaching science and across all subjects in elementary classrooms.
Need to identify how long-term cuts to instructional materials impact the reform efforts of the NGSS.
Need to identify how teachers' modifications to instructional materials impact student progression through the NGSS or State Learning Outcomes across the grade levels.
Need for a broader study that includes urban teacher interviews and teachers of color.

Implications for Teachers
Attend to all three components of science standards during the planning and delivery of science lessons. Provide feedback to administrators regarding time for the preparation of materials. When available, choose opportunities to attend professional development offerings related to science standards and instruction.
Implications for Administrators
Understand teacher needs for effective science instruction and provide support for those needs. Adjust schedules to make room for science and social studies. Allow all instructors of science to attend professional development training on new materials. Consider adding a position to staff that supports science instruction in elementary schools.
Implications for Professional Development Providers
Instruction on how to use module instructional materials does not mean that teachers understand how the materials address the NGSS, nor does it change the mindset of some teachers about what constitutes good science instruction. Therefore PD might provide further services to teachers that address the intersectionality of the materials and standards as well as the fundamental differences between traditional science teaching and the philosophy and goals of the NGSS.

Implications for Further Research

Pressures on teachers to have students perform well on standardized tests are well documented in the literature. Science and social studies instruction often does not receive the priority status in elementary schools that mathematics and ELA, the tested subjects, hold. Nevertheless, we know that metrics show that students in the US score lower than students in other developed nations in their science knowledge (NCES.ed.gov). The Next Generation

Science Standards aim to improve science instruction for all students. Currently, 20 states have adopted the standards as written, and 24 others use standards informed by the Framework from which the NGSS were developed. New York, for example, has its own set of science standards, but at the elementary level, they are nearly identical to the NGSS. (https://www.edreports.org/resources/article/data-snapshot-k-12-science-instructional-materials)

This study points out that when districts have adopted instructional materials, such as the SSEC, that align with the new standards, teachers make decisions about science instruction that imply a lack of understanding of the standards or where and how the lessons and the standards connect. This study shows that teachers eliminate lessons or portions of lessons regularly. Well-meaning teachers say they consult the standards to guide their decisions about what to eliminate but still give students learning opportunities. However, when teachers consult the standards, they focus on the science content of the standard only. Not attending to the scientific practices or the crosscutting concepts during the decision-making process implies a lack of understanding of the three-dimensional nature of the standard. Recall how Shelley and Roberta, noted that they did not get to the culminating lessons at the end of the unit. These teachers' students miss the opportunity to use the integration of the three dimensions of the standards to demonstrate their understanding of the phenomena and answer the question put forth in the unit title. This is not only a missed opportunity for assessment by the teachers but also for students to experience a chance to see how the dimensions of the standard combine to create knowledge that they then apply to complete the final task, just as scientists apply their newfound knowledge to different questions, and engineers to different problems. Therefore, future research is needed to identify what opportunities teachers have to learn about the standards in general and specifically how the NGSS stresses the integration of all three dimensions of each particular standard in the units.

Future research in this area would have implications for teachers' better understanding of the importance of teaching science in a manner that ensures that all three dimensions of the standards are addressed.

Teaching in ways that reflect the current standards presents an issue regarding assigning grades. Traditionally, students could take quizzes on content and vocabulary along with an end-of-unit test, all of which could produce grades for report cards. The current standards do not promote such testing, and the SSEC lessons supply a rubric at the end of each lesson and an extensive rubric at the end of the unit. A place for future research may be to interrogate what teachers know about using a rubric for grading and how using the rubrics can translate into current report cards that require a number or letter grade. Perhaps teachers need an opportunity to use rubrics for science instruction or do not feel they can use them because they do not align with their report card format.

A further example of the need to know more of what teachers understand about the NGSS is exemplified by teachers feeling the need to “add content” to the instructional materials. Student sense-making by gathering evidence from investigations, making and changing models, and drawing conclusions as new knowledge is acquired is encouraged in the standards over in-depth explanations of topics and sessions of fact dissemination by teachers. Future research would suggest that if this is a pattern among teachers, it has implications for the opportunities teachers need to learn how instructional materials advance the goals of the NGSS.

Lack of time was the primary reason teachers in both the survey and in interviews eliminated or made modifications to lessons. Recall that even in cases where teachers reported having enough class time devoted to science instruction to deliver the SSEC lessons of 40 minutes each, they cited lack of time as the primary reason for making changes. An opportunity to watch teachers deliver the lessons might reveal issues that hinder the instructional minutes, such as interruptions from phone calls from the office or students coming and going for services delivered outside the classroom. Teachers could also provide insight for developers that show a divergence between how developers imagine the lessons unfolding and how they unfold in real time. Research into how teachers spend their science instructional minutes could indicate that some teachers are working from a traditional mindset of how to teach science by going further into depth than the standard requires, using minutes to explain concepts that the investigations are designed to allow students to come to on their own, or making assumptions about the students' abilities that cause them to add explanation where it is not needed. Studying science teaching at the classroom level can lead to solutions on the teaching level, the administrative level, the professional development level, or the developer level that can support teachers and lead to better instruction for students. It's also possible, however, that the study would reveal that other strategies, such as lengthening the school day and paying staff accordingly, is the only path forward.

Connected to time, teachers also reported that often they do not get to the last two lessons in the unit. These two lessons are the culminating activity for the unit where students are asked to synthesize all the learning from the unit and apply it to the task laid out in those lessons. Students miss the opportunity to show teachers what they understand about how the DCIs, SEPs and CCCs come together to inform their understanding of the phenomenon featured in the unit. Additionally, by not getting to these lessons, teachers do not get the opportunity to collect information about student learning. We need to understand more about what can be done to allow teachers to get to these important lessons.

In addition to how teachers use instructional minutes in science, future research is warranted to study minutes used in a school day in a broader sense. A study of how time is used within the school day could reveal many minutes that are not used for instruction, including transition times, time taken for arrival and dismissal, getting "ready" for lunch, and time for students to attend special programs. Perhaps a study would reveal more time is taken for these activities than is required.

A broader study of the school day should also include the teacher's workday. A study of teacher time would likely reveal that they often can not attend to tasks directly related to their teaching due to duties required of them by administrators, such as committee membership and faculty and data meetings. A broader study of the use of *all* minutes in a school day could reveal a need for more efficient use of time, which can, in turn, recapture minutes for preparation and instruction.

Every interviewee in this study said they changed the lessons in some way. Some eliminated lessons, some added materials to lessons, and some changed the materials to suit their students' perceived needs. Future research is needed to evaluate the long-term effects of these changes on both the reform efforts of the NGSS and the learning outcomes for students. Even though teachers across the country are using the SSEC materials, they are not doing so uniformly, and some variation exists even among teachers who follow the unit lessons very closely. It is reasonable that teachers use their personal style to teach the units, which will result in some variation. That is to be expected. However, the variations in rationales for changes in the unit alone are enough to see that students from class to class in the same grade level in the same building, much less a different building in the same district, can receive different instruction. When we multiply that over various districts and states, we see that the trajectory that the NGSS promoted, and the developers intended is likely lost. With all of this change within one set of publisher materials, we should be concerned about teachers still using pre-NGSS developed materials, writing their own material based on interpretations of the NGSS that may or may not be what the writers intended, or buying materials from the Internet that may not align with the new standards. How much change can we incur before the instruction no longer represents the NGSS? How much change can we incur before the instructional materials no longer resemble the unit the developers, those with expertise in curriculum writing, intended? Most importantly, how much change before the students do not get the science education that the NGSS and the materials intended?

Future research on the long-term effects on learning outcomes for students subject to teacher cuts to the curriculum from year to year is a vital implication of this study. With teachers making cuts to lessons designed to allow students to address the standards fully, possible gaps in student learning could develop, especially given the considerable variation in what teachers cut and why. In extreme situations, teachers, from grade to grade, could cut the same lessons yearly. For example, lessons where students make claims and provide evidence for those claims appear at every grade level. However, providing evidence-based explanations from text is also a Common Core Standard for ELA. Teachers may determine that since students get that experience in ELA, they do not need to teach lessons that emphasize claims and evidence in science, and to save time, cut lessons or portions of lessons where these skills are employed. However, in science, students use logic and reasoning to make claims and provide evidence from their investigations or science text materials to compare with their peers, determine validity, and often determine the best possible answer to a question or solution to a problem. Therefore, scientific claims and evidence are not used in the same context as in ELA.

Cutting and modifying lessons from the units has implications for the success of the science education reform efforts that the NGSS were designed to advance. Suppose teachers like Carl continue to believe that imparting facts means good science teaching and therefore replace student activities from NGSS-aligned curriculum with notetaking and fact dissemination. In that case, the efforts of the NGSS to allow students to develop their learning through scientific practices are compromised, and science instruction reverts to pre-reform pedagogies.

A final implication for future research is the need for a broader, more diverse study that includes urban teacher interviews and more teachers of color. Recall that in this study, all interviewees were white with rural and suburban backgrounds, with one exception. Some conclusions can be drawn based on responses from these teachers, and urban schoolteachers might have similar issues with time and space and misunderstandings about the standards. However, urban teachers often face more prevalent challenges than suburban and rural schools, such as truancy, poverty, English language proficiency, and family instability, affecting all aspects of education (https://nces.ed.gov). Therefore, the perspectives of urban teachers are vital to include in any study of science teaching at the classroom level.

Implications for Teachers

When teaching science according to the standards, teachers must consider the Science and Engineering Practices and Crosscutting Concepts instead of focusing only on the Disciplinary Core Ideas. The responses from the interviewees indicate that when teachers decide what to teach, their primary focus is on the content portion of the standard. While content is essential, it is also vital that students get multiple opportunities to engage in the practices and connect different strands of science through Crosscutting Concepts. In the current climate where teachers cut material due to time constraints and emphasis on other areas, it is important that they consider the consequences to student learning not only in terms of content but also in the other dimensions of the standards.

Teachers must also communicate with administrators the need for adequate preparation and teaching time for science instruction. Administrators know that science standards exist and are more rigorous than previous versions. However, they rely on classroom teachers for implementation and do not typically attend training. The materials required for teaching to the standards require preparation time and space that teachers need to have. Interviewees discussed the push for emphasis to be placed on ELA and mathematics in order to prepare students for testing. This emphasis may be beyond the teacher's control and a common issue across districts. However, if teachers can involve administrators more closely in what it takes to teach to the standards, perhaps administrators would be willing to work with them toward solutions.

The study data implied that teachers could benefit from science-related professional development opportunities when offered. The participants in this study show areas where they need to understand the trajectory the standards take more fully. Specifically, teachers may find professional development helpful in understanding how the three dimensions of the standards interrelate to help students understand science concepts, how scientists developed them, and how they relate to other science areas.

Implications for Administrators

Administrators need to ensure that teachers have opportunities to attend PD and collaborate with peers to boost understanding of the science standards, an essential step in ensuring that the vision of the standards remains intact. As outlined in the NGSS, science instruction affords the students opportunities to achieve the appropriate level of instruction as grade levels progress. When teachers are forced to train themselves, or only one teacher in a group is allowed to attend PD for training but is then expected to train colleagues, the potential arises for the turnkey teachers to insert their own beliefs and attitudes about the materials. This creates a possible misinterpretation of the standards, materials usage, or both.

It was beyond the scope of this study to include survey and interview protocols for administrators. However, the study revealed that teachers face difficulties in delivering science instruction due to systemic constraints. The study revealed that the time it takes for science lesson preparation and setup impacts what teachers can teach from their science units. The setup of materials is typically included in a single planning period that must be shared with many other responsibilities for the teacher. Along with time, space for investigation materials to remain set up or stored was also an issue in how instructional materials are used. Lack of time and space impact what and how materials are used. It would be useful to know how administrators understand the NGSS and how the constraints on time and space impact how teachers teach science.

Along with time, space for investigation materials to remain set up or stored was also an issue in using instructional materials. Lack of time and space impact what and how materials are used. It would be helpful to know how administrators understand the NGSS and how the constraints on time and space impact how teachers teach science and use the materials. Perhaps a professional development component for administrators could add to their understanding of teacher needs.

In schools with someone designated to oversee science instruction and assist teachers, the instruction was more likely to follow the lessons in the teacher manual. That is not to say that even with support, teachers did not make hard decisions about eliminating some lessons or portions of lessons. However, the instruction for the students in that school was more consistent

over the grade level, and teacher support appeared to make teaching science more manageable. Administrators might consider creating such a position in their schools if one does not exist.

To add to an administrator’s understanding of how the science lessons, including preparation, are delivered in real time, it might be beneficial for administrators to observe a science lesson. Observations tend to be focused more on math and literacy than science (and social studies) Observing a lesson may help the administrators understand the complexity of delivering a lesson that meets the standards at the elementary level and compel them to advocate for more minutes in the day or week devoted to science preparation and teaching. In the interview phase of this study, several teachers noted that the time allotted for science instruction was nowhere near the time allotted for ELA and math, but the allotments were mandated by the administration and out of teacher control. An observation by administrators may help them realize that teachers need more time if they are to deliver adequate instruction in science.

In schools with someone designated to oversee science instruction and assist teachers, the instruction was more likely to follow the lessons in the teacher manual. That is not to say that even with support, teachers did not make hard decisions about eliminating some lessons or portions of lessons. However, the instruction for the students in that school was more consistent over the grade level, and teacher support appeared to make teaching science more manageable. Administrators might consider creating such a position in their schools if one does not exist.

Implications for Professional Development

The need for more research on how teachers understand the NGSS has implications for other areas as well, including professional development. Knowing how teachers understand the NGSS can facilitate changes in PD offerings and training opportunities to include specific attention to where and how all three dimensions of the NGSS standards are interwoven into the lessons when teachers are being trained on NGSS-aligned units. This may take longer than the typical two-day module training many of this study's respondents received. Two training days may help teachers become familiar with the module products but may not be long enough to internalize how a unit weaves together opportunities for students to address all dimensions of the focus standards, nor change a mindset where teachers believe that good science teaching is achieved when students can recite scientific facts. In comparing effective professional development models, Heckathorn (2022) describes common qualities of effective professional development, such as allowing for teacher collaboration, being content-focused, and including active learning. Two qualities of effective professional development, sustained duration and providing opportunities for feedback and reflection, appear to only occur in very few instances for the participants in this study. When participants engage in professional development of sustained duration, they receive adequate time to learn, practice, implement, and reflect on the work. Teachers have enough time and opportunity to gain a strong understanding of the work they are being asked to undertake and the materials with which they will implement the work. Undertaking the implementation of the NGSS and materials that align with those standards is a large task, and the typical two-day instruction that most of the interviewees received as training was likely inadequate. In addition to participating in sustained duration, teachers who engage in professional development where they can receive feedback that can ultimately result in better learning outcomes for students. Many interviewees mentioned that accessing someone with a strong knowledge of the standards and/or the materials was difficult. Recall that only Ireland is in constant contact with her elementary science colleagues after the initial training.

Further Ideas

Although not included in this study, the findings suggest that other stakeholders may be influential in eliminating some of the difficulties teachers face when preparing for and teaching science adequately. Most interviewees noted that the emphasis on ELA and math instruction because of state-mandated testing in these areas impacts the amount of time available to spend on science and social studies preparation and instruction. Teachers note that because of state and federal educational policies, some school administrators dictate a certain number of minutes to be spent on ELA and math daily, leaving much less time for teaching science. Once physical education, art, music, lunch, and recess factor into the school day, science might be relegated to 30 minutes just a few times a week, and even then, it may have to alternate with social studies. Test preparation in ELA and math before the state tests further limits science instruction time. Policies that tie teacher evaluations and district funding to state test scores negatively impact the opportunity for students to learn other subjects, and lawmakers need to consider alternative measures to hold schools accountable.

One does not typically think of teacher unions as influential in providing solutions to elementary teachers' issues when preparing for science instruction. However, teachers in this study mentioned that they have one planning period that has to include setting up for science instruction and all the other duties. As a result of completing this study, I would like to know if something added to teacher contracts could address the time it takes to prepare materials for instruction in elementary classrooms. Compensation for extra time before or after the regular school day to allow teachers to prepare the extensive materials could be considered. If school districts expect science instruction to occur in accordance with the current standards, it should supply teachers with what they need to do so.

Summary

Although this study is small and has limitations, the results can inform future research about how teachers use instructional materials for science teaching in the elementary grades. The study points to specific actions that teachers are taking, often to do what they believe is best for their students, but may cause gaps in science knowledge. The study also indicates implications for teachers, administrators, professional developers, and instructional materials developers. Many "fixes" to issues interfering with quality science instruction for students lie beyond the teachers' control but require a more systemic solution. Decisions made by policymakers and administrators trickle down to the classroom teacher to carry out. Issues such as lack of time to prepare materials and deliver instruction require changes at the administrative level. Still, those changes may not readily come about if changes do not occur at the policy level. This study shows that change is possible only when all stakeholders are well-informed.

The past reform efforts in science education have yet to create improved student outcomes successfully. Like the efforts of the past, the NGSS guide instruction designed to improve student outcomes for all students, and instructional materials exist that support those intentions. Students must have the opportunity to benefit from those efforts, but this will only come about through quality professional development and decisions by policymakers and administrators that support the effort.

Appendix A

Use of Smithsonian Instructional Materials Survey Questions

Start of Block: Demographics

Q1 Gender

- ☐ Female (1)
- ☐ Male (2)
- ☐ Non-binary (3)
- ☐ Prefer not to say (4)
- ☐ Click to write Choice 5 (5)

Q2 Race

- ○ White (4)
- ○ Black or African American (5)
- ○ American Indian or Alaska Native (6)
- ○ Asian (7)
- ○ Native Hawaiian or Pacific Islander (8)
- ○ Multi-race (9)

Q3 Which choice below best describes the district in which you teach?

- Urban (1)
- Suburban (2)
- Rural (3)

Q4 How many years have you been teaching in grades K-5?

- 1-5 (1)
- 6-10 (2)
- 11-15 (3)
- 16-20 (4)
- 21+ (5)

Q5 Current Grade Level

- Fourth (1)
- Fifth (2)

Skip To: Q7 If Current Grade Level = Fifth

Q6 Which of the following fourth grade Smithsonian Science for the Classroom units have you taught in the past 5 years? Please check all that apply.

- ☐ How Can Animals Use Their Senses to Communicate? (1)
- ☐ What is Evidence We Live on a Changing Earth? (2)
- ☐ How Does Motion energy Change in a Collission? (3)
- ☐ How can We Provide energy to Peoples' Houses? (4)

Q7 Which of the following fifth grade Smithsonian Science for the Classroom Units have you taught in the past 5 years? Please check all that apply.

- ☐ How Can We Predict Change in Ecosystems? (1)
- ☐ How Can We Use the Sky to Navigate? (2)
- ☐ How can We Identify materials Based on Their Properties/ (3)
- ☐ How Can We Provide Freshwater to Those in Need? (4)

Q8 How many weeks per school year do you typically teach science to your class?

- ○ Less than 10 weeks (1)
- ○ 11-20 weeks (2)
- ○ 21-30 weeks (3)
- ○ 31-40 weeks (4)

Q9 How many days per week do you typically teach science?

- ◯ 1 (1)
- ◯ 2-3 (2)
- ◯ 3-4 (3)
- ◯ 5 (4)

Q10 On average, about how many minutes long are your science lessons?

- ◯ Under 30 minutes (1)
- ◯ 30-45 minutes (2)
- ◯ 45 minutes to an hour (3)
- ◯ Over one hour (4)

Page Break

Q11 How many years have you been using the Smithsonian Science materials (Smithsonian Science in the Classroom or STC)? Note: Your Smithsonian Science module materials are provided by Carolina Biological Supply and may be distributed by a regional distribution center. Please consult your teacher manual if you are unsure.

- ◯ 1 year (1)
- ◯ 2 years (2)
- ◯ 3 years (3)
- ◯ 4 years (4)

Q12 Have you taught from kit based science materials prior to using the Smithsonian materials (i.e. Foss, Gems, Delta, locally developed materials)?

- ◯ Yes (1)
- ◯ No (2)

Q13 How did you receive initial training for the Smithsonian units that you teach?

- ◯ I trained myself to teach the unit. No other training was provided. (1)
- ◯ My colleagues and I worked together to teach ourselves. No other training was provided. (2)
- ◯ I received training from an in-district trainer. (3)
- ◯ I received training from a regional trainer. (4)
- ◯ I received training from the Smithsonian directly. (5)

Q14 How much control do you have over determining the amount of instructional time to spend on science?

- ◯ A great deal (1)
- ◯ A moderate amount (2)
- ◯ A little (3)
- ◯ None at all (4)

Q15 How much control do you have over the selection of topics, content, and skills to be taught?

- ◯ A great deal (1)
- ◯ A moderate amount (2)
- ◯ A little (3)
- ◯ None at all (4)

Q16 How much control do you have over the selection of Smithsonian materials to use for each lesson?

- ◯ A great deal (1)
- ◯ A moderate amount (2)
- ◯ A little (3)
- ◯ None at all (4)

Q17 How often do your students engage in the following practices?

	Every lesson	More than ½ the time	Less than ½ the time	Never
Generate Questions	○	○		○
Conduct a scientific investigation (2)	○	○	○	○
Organize and represent data (3)	○	○	○	○
Make and support claims with evidence (4)	○	○	○	○
Determine what data would need to be collected in order to answer a scientific question (5)	○	○	○	○
Develop procedures for a scientific investigation to answer a scientific question (6)	○	○	○	○
Analyze data (7)	○	○	○	○
Develop models (8)	○	○	○	○

Use data and reasoning to defend a claim or refute alternative scientific claims (9)	○	○	○	○
Identify the strengths and limitations of a scientific model (10)	○	○	○	○

Q18 In your most recent science **lesson,** in which activities listed below did your students participate? Please check all that apply.

- ☐ Whole class discussion (1)
- ☐ Teacher explaining a science idea to the whole class (2)
- ☐ Students working in small groups (3)
- ☐ Students doing hands-on/laboratory activities (4)
- ☐ Students reading about science (5)
- ☐ Students writing about science (6)
- ☐ Teacher conducting a demonstration while students watched. (7)

Q19 How often do you use SCIENCE lessons or resources from websites that have a subscription fee (BrainPop, Discovery Ed, Teachers Pay Teachers, etc)?

- ○ Once a month (1)
- ○ several times per month (2)
- ○ Less than once a month (3)
- ○ Never (4)

Skip To: Q22 If How often do you use SCIENCE lessons or resources from websites that have a subscription fee (Bra... = Never

Q20 If you use any of the above, please write the name of the resource you tend to use most often?

____

Q21 If you answered question number 17, please state WHY you tend to use this resource.

____

Q22 **In addition** to the materials from the Smithsonian Science Modules, how often do you use the following in science lessons.

	Several times per month (1)	occasionally (2)	Never (3)
Lessons you created alone or with colleagues (1)	○	○	○
Lessons you collected from any other source such as conferences, journals, colleagues, university or museum partners (2)	○	○	○
Lessons from web sources that are free such as Khan Academy (3)	○	○	○
Supplemental reading materials such as ScienceNews, Scholastic News, Literacy curriculum (4)	○	○	○

Q23 In which of the following ways did you substantially use the Smithsonian materials **in your most recent unit?**

	consistently (1)	occasionally (2)	rarely (3)	never (4)
I used the materials to guide the structure and content emphasis of the unit (1)	○	○	○	○
I incorporated activities (e.g. problems , investigations, readings) from other sources to supplement these materials (2)	○	○	○	○
I modified activities from these materials (3)	○	○	○	○
I picked what is important from these materials and skipped the rest (4)	○	○	○	○

Q24 From the list below, please check all reasons that apply for why you have **skipped** lessons Smithsonian lessons in any unit.

- ☐ I did not skip any lessons (1)
- ☐ I did not have enough instructional time for the activities that I skipped (2)
- ☐ I have different activities for those science ideas that work better than the ones I skipped (3)
- ☐ The activities that I skipped were too difficult for my students (5)
- ☐ I did not have the knowledge that I needed to implement the activities that I skipped (6)
- ☐ My students already knew the science ideas (7)

Q25 From the list below, please check all reasons that apply related to why you have **supplemented** Smithsonian materials.

- ☐ I had additional activities that I liked (1)
- ☐ Supplemental activities were needed to accommodate different levels of achievement. (2)
- ☐ Supplemental activities were needed to provide students with additional practice (3)
- ☐ Supplemental activities were needed to prepare students for standardized tests (4)

Q26 From the list below please check all that apply to why you have made changes to the Smithsonian materials. (Example: changed a recording sheet in some way, changed the order of lessons, etc, directed students to skip certain questions during an activity)

- ☐ I did not have enough instructional time to implement the activities as designed (1)
- ☐ The original activities were too structured for my students (2)
- ☐ The original activities were too difficult conceptually for my students (3)
- ☐ The activities were not structured enough for my students (4)
- ☐ The original activities wre too easy conceptually for my students (5)
- ☐ The lesson format did not meet the needs of my current students (6)

End of Block: Demographics

Start of Block: Block 1

Q28 If you would like to be entered into a drawing for one of ten $10 Amazon gift cards as a thank you for completing the survey, please enter your email below. This is completely optional and the email will only be used to notify winners.

Q27 Would you be interested in discussing the use of the Smithsonian Science Materials in your classroom in a phone interview with me? (The interview will last no longer than 30 minutes and you will automatically be entered into a drawing for one of four $50 Amazon gift cards as a thank you. You will be sent a notice of how the data will be used and how your privacy will be protected prior to the interview.

- ○ Yes, I would be willing to participate in the interview. My contact email is: (4) ____
- ○ No I would not be interested in participating in the interview. (5)

Appendix B

Emails Sent By State, Number of Districts, And Number of Schools

State	Number of Emails Sent	Number of Districts	Number of Schools
California	14	1	3
Colorado	163	4	27
Connecticut	53	3	4
Massachusetts	183	3	42
New Jersey	10	1	3
New York	431	32	78
Oregon	26	1	3
Pennsylvania	127	6	19
Virginia	64	1	8
Washington	283	10	77
Totals	**1354**	**62**	**264**

Appendix C

Semi-Structured Interview Questions

1. Would you please describe your teaching environment (urban, suburban, rural, grade, ELL etc.)
2. How long have you been teaching?
3. How long have you been using SSEC materials?
4. Which units have you taught?
5. How familiar are you with the NGSS (or your state version?) Can you describe how you use them in your science teaching?
6. Describe your science teaching schedule.
    a. How many days per week?
        i. How many minutes per lesson?
7. What training did you receive on the unit?
    a. Duration of the training session?
    b. Follow-up sessions?
8. Describe your overall feeling about the units.
9. Would you please walk me through how you prepare to teach a Smithsonian Science unit when you receive your kit?
10. Please describe how you prepare for an individual lesson.
11. Can you describe how you use the component materials in the unit? (Readers, work pages)
12. Please describe what lesson or section of a lesson you might choose to skip.

Follow Up: Why do you skip these lessons or sections of lessons?

13. Can you tell me about any modifications or changes you make to the SSEC materials, if any?
    a. Follow Up: Why do you make these changes to the materials?

14. Can you tell me anything you might add to the SSEC units and why you add them, if any?
    a. Follow-up: Why do you make these additions?
    b. Can you name specific additions you make regularly?

Is there anything else you would like to say about the SSEC materials?

Follow-up Questions Frequently Asked:

1. Do you have suggestions for the SSEC developers for improving the materials? Can you please explain why?
2. Are any of these changes directly related to the COVID pandemic and its impact on your teaching?
   Follow-up: Are you planning to keep any of these changes now that the school days and weeks are back to pre-COVID schedules?

Appendix D

Survey Question Number, Description, And Number of Respondents

Question Number	Description	Number of Respondents
1	Gender of respondent	54
2	Race of respondent	54
3	District type	54
4	Years of teaching experience	54
5	Grade Level	55*
6	Fourth grade SSEC units taught in past year	54**
7	Fifth grade SSEC units taught in past year	89**
8	Number of weeks per school year teaching science	51
9	Days per week teaching science	51
10	Minutes per science class	51
11	Years using SSEC	50
12	Prior experience with kit-based science	50
13	Training on SSEC	51
14	Control over science instructional time	51
15	Control over topics	51

Question Number	Description	Number of Respondents
16	Control of use over SSEC materials lesson	51
17	Science and Engineering Practices	45
18	Science activities	220 **
19	Subscription website use	45
20	Names of website subscriptions	Fill-in
21	Reasons for using subscriptions	Fill-in
22	Frequency of lesson style	42
23	Use of SSEC materials	42
24	Reason for skipping SSEC Lesson	50
25	Reason for supplementing SSEC materials	50
26	Reasons for modifying SSEC	50
27	Submission of email for drawing of Amazon gift card	29
28	Submission of email for interview	17

* STEM teachers teach more than one grade level. Therefore, they are responding to both grade-level choices in the survey. ** Teacher selected "all that apply"

Appendix E
Codebook

Code	Description	Files	References
Lessons			
Content	Positive and Negative perceptions of content	`12	31
Difficulty	Statements regarding the difficulty of lessons	7	14
Quantity	Statements regarding the amount of material to be covered in single lessons	4	9
Length	Concerns re: length of lessons	6	7
On-site assistance	Statements re: available assistance with SSEC questions/materials	4	7
Notebooking	References to notebook writing and usage	7	29
Readers	References to usage of readers provided in modules	3	4
Preparation	Steps in lesson preparation	12	21
Investigation Materials			
Teacher Manual	Teacher description of how the teacher manual is used during lessons	6	14
Hands-on materials	Statements regarding usage of module materials	12	16
Code	**Description**	**Files**	**References**
Changes to Lessons			
Pick and Choose	Statements containing " picking and choosing" materials from lessons	5	10
Additions to Lessons	Resources added to SSEC lessons (other)	8	48
Extension Activities	Additions to lessons chosen from module extension activities	2	3
Rationale for additions	Rationales provided by teachers for adding to	8	25

Code	Description	Files	References
	SSEC		
Modification of physical materials	Change something in lesson but maintain lesson structure i.e. adding sentence starters to data sheet; enlarging writing space	9	27
COVID pandemic-specific changes	Special change to accommodate change in schedules/teaching format due to COVID (not anticipated to be permanent)	12	19
Skip (eliminate) Lessons	How teachers determine which lessons or parts of lessons to skip	8	20
Full Lessons	Statements regarding skipping full lessons	6	10
Rationale	Rationales presented for skipping full lessons	8	19
Partial Lesson	Description of what parts of lessons are skipped	7	12
Rationale	Rationales presented for skipping parts of lessons	7	10

Code	**Description**	**Files**	**References**
Substitutions	Teacher substitutes a different resource for lesson description. The inserted item may or may not be from SSEC I.e. Teacher takes out hands-on and inserts video	8	19
Rationale	Rationale for substitutions	8	17
Reference to new science tests	Teachers make reference to decisions based on perceptions of new science test requirements	7	11
Schedule	Reports of science teaching schedule	12	13
Time	Teacher statements regarding time in preparation and delivery of lessons	12	34
Demographics			
District Description	Rural Urban Suburban (approximate # of students)	12	19
Teaching Position/Class and School Size	Position, school size, class size	12	32
Teaching experience	Total teaching years	12	23

Science Teaching Experience	Number of years teaching science in total	12	11
SSEC teaching experience	Number of years teaching SSEC units (current edition)	12	19
SSEC Units taught	SSEC units currently in rotation and taught	12	11

Scientific method	Teacher reference to scientific method	2	4

Code	**Description**	**Files**	**References**
Standards	Teacher references to state standards	7	12
Suggestions for improvement	Teacher suggestions for making the units "better"	11	29
Teacher emotions/feelings	Expressions of personal feelings about teaching the SSEC units	9	46
Unit Preparation			
Training for SSEC	Initial training for SSEC units	12	24
Planning for Units	Team and Individual planning at classroom/grade level	12	17

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EDUCATION

Syracuse University Syracuse, NY
Ph.D., Science Education Graduate May 2024

Syracuse University Syracuse, NY
MS Elementary Education, Summa Cum Laude Graduated 1992

Syracuse University Syracuse, NY
BS Social Work, Summa Cum Laude Graduated 1978

PROFESSIONAL EXPERIENCE

Graduate Assistant August 2020-present
Syracuse University School of Education Syracuse, New York
My duties include assisting Dr. Sharon Dotger in preparing for and teaching elementary science education courses at Syracuse University School of Education and teaching EED 337 (Methods and Materials in Elementary Science Education) to pre-service teachers. These responsibilities include teaching classes, grading assignments, and assisting students with implementing science lessons on campus and in field placements.

K-6 Science Instructional Specialist September 2016-June 2020
Marcellus Central Schools Marcellus, NY
My duties included *overseeing the implementation of the New York State Science Learning* Standards and the Smithsonian Science materials provided by BOCES to K-6 teachers in the Marcellus CSD. These responsibilities included co-teaching, providing in-house ongoing training, and troubleshooting issues with implementing new modules.

Science Lab Instructor K-6 September 2009 - June 2016
Marcellus Central Schools Marcellus, NY
My duties included developing a curriculum aligned with Common Core and NYS Science Curriculum, integrating STEM instruction, and delivering hands-on laboratory experiences to all K-5 students (Grades K-2 monthly, Grades 4-5 weekly). I also provided Earth Science lab experiences (Grade 6 weekly) and maintained two science lab spaces.

Science Content Specialist K-6 September 2012 - Present
Marcellus Central Schools Marcellus, NY
My duties included disseminating information regarding standards and curriculum to K-6 science teachers and working with classroom teachers to align and integrate STEM instruction into classroom science.

Classroom Teacher, Sixth Grade September 1992-June 2009
Marcellus Central Schools Marcellus, NY
My duties included delivering instruction in all subject areas to sixth-grade students. The science instruction included all areas of general science.

PROFESSIONAL CERTIFICATIONS AND PARTICIPATION

Lesson Study Team Presenter/Panelist November, 2017
It's Go Time March 2019
Science Lesson Study Conference
Syracuse University

Project Advisor
Smithsonian Science for the Classroom 2017
How Can We Protect Animals When Their Habitat Changes
Smithsonian Science Education Center, Washington, DC

National Board Certification 2006-present
Middle Childhood Generalist

Mickelson Exxon Mobil Teacher Academy Summer, 2013
Jersey City, NJ

PERSONAL INTERESTS

Spending time with family, reading, cooking, swimming, biking, crocheting