Leveraging Current Instructional Practices to Achieve Disciplinary Literacy in a Fifth Grade Science Classroom

by

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DEDICATION

I dedicate this dissertation my sweet Gramma who assured me I can "never go wrong with an education" and reminded me to make up my face.

ACKNOWLEDGMENTS

Growing up, whenever my sister and I would make a mistake, such as getting a snowmobile stuck in a tree, our dad would grumble, “What’s the matter with you?” while he dug us out–sometimes literally–of the situation. In contrast, whenever Dad made a mistake, he would look at my sister and me and say, “Look what we did.” As I put the finishing touches on this dissertation, I cannot help but look around at all the people who have encouraged and helped me and sincerely think, “Look what we did!”

I am immensely grateful for my parents for always being my biggest fans. My parents taught me to read, calculate, and reason and supported my reading habits and music lessons. They gave me a love for learning by sharing their own fascination with the world. We enjoyed riding around the cemetery to find amazing persons and honored veterans, driving through fields to count deer, lying under the stars to “feel the Earth move,” and celebrating firsts–the first dip in the ocean, the first haircut, the first days of school, and importantly, the first day of the rest of my life. They have never told me my dreams are impossible.

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Brandon is amazing. We are always his priority. Brandon lived with my parents, drove two hours to and from work, and travelled 13 hours round trip every weekend to be in Ann Arbor with me. At home, he literally cheers for me while I work. His sacrifices and love have made this degree as much his as mine.

I would also like to acknowledge my dear Gramma and Papa. They celebrated every milestone with me until their passing, and every day I am reminded of their unending support and love. They graciously participated as “students” when I practiced lessons for my undergraduate coursework and slipped me gas money before I went back to the dorms for the week. They were proud of me, and because of that, I worked hard to validate their pride.

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Neither my doctoral work nor this study would have been possible without the graciousness of Mrs. Poppy and her students and the financial support of the Rackham Merit Fellowship Program and the Michigan Indian Tuition Waiver. I am honored to have had the Fellowship’s trust in my abilities and to represent my tribal community. Miigwech.

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ABSTRACT

Historically, reforms designed to transform teaching from rote, teacher-centered instruction to progressive student-centered instruction have had varied levels of success. Plentiful research juxtaposes teachers' enacted instruction with the instructional ideals of reform efforts to determine the extent to which teachers' instruction aligns with reform-based science education standards. Discrepancies and continuities are frequently explained by the mediating effects of the instructional context. While this information is valuable and establishes the strong interdependent relationship between context and instruction, little research attends to the capacity of specific contexts to support reform-based instruction. In this dissertation, I explore the liminal space between science reform adoption and reform implementation in a rural, fifth grade classroom. I immersed myself in a veteran teacher's classroom context for two units of study, the solar system and "The Scientific Method." Using Creswell's (2013) iterative, inductive approach along with tools from content and discourse analysis, I analyzed interview recordings and transcripts; classroom observation recordings, field notes, and digital photographs; and classroom artifacts to examine how contextual resources and constraints shape the teacher's instructional practices and the extent to which her existing practices align with reform-based ideals and practices. Findings indicate that the teacher's accessible resources (e.g., her own education, school provisions) and professional expectations (e.g., previous standards, school policies) position science as a set of disciplines comprised of a discrete facts that are learned through low-level cognitive tasks of recalling and understanding content and procedural

knowledge. Nonetheless, in accordance with the National Academies' call for context-specific instructional support, this study identifies existing pedagogical practices that can be leveraged to achieve instruction that more closely approximates reform-based instructional practices and considers the potential for developing teachers' instructional practices through zones of feasible innovation (Rogan, 2007). I detail the process for identifying zones of feasible innovation for the participating teacher's instruction as a model for designing individual learning trajectories with examples from the instructional context analyzed in this dissertation.

Findings and conclusions from this study highlight the need for teacher conceptual change through reflective practices and dialogic interactions. Moreover, this study also suggests school leaders will need to ensure that school structures allow teachers adequate planning and instructional time for science as well as access to technology and spaces appropriate for science activities. Finally, this study establishes a need for equitable access to professional learning opportunities and more research exploring avenues for supporting teachers in their individual, diverse contexts (e.g., open-access, virtual educative curriculum materials), particularly those with limited resources in isolated locations.

CHAPTER I

Introduction

On a typical Midwestern spring afternoon, Mrs. Poppy, a pseudonym, and her students reviewed content from the previous lesson by watching a brief infographic video about the tilt of the Earth. Following the video, Mrs. Poppy read aloud a short paragraph from a packet of worksheets that students had previously received. She directed their attention to sentences they should highlight and asked comprehension questions about the text. Then, using a globe and a small lamp, Mrs. Poppy demonstrated the Earth's tilt and explained misconceptions about the cause of the seasons.

"I want to show you something," she said. "A lot of people think that as it goes around, the tilt stays facing the sun like that, and it like turns so that it's tilted toward the sun all the time…That's not what happens…If we are tipped like this, and we are going around, it stays like this, guys, as it goes around the sun...It's important that you know that."

Taking the globe to one side of the room, Mrs. Poppy continued, "We are going to start off over here." Mrs. Poppy held the globe so the Northern Hemisphere was tilted toward the sun. "What do you notice about the Northern Hemisphere right now? Where is it facing?"

The students did not respond, so Mrs. Poppy answered, "It's tipped toward the sun…We are having summer."

After a short discussion about how difficult it is to think that in the Northern Hemisphere June is in the summer but in the Southern Hemisphere Christmas is in the summer, Mrs. Poppy explained that the seasons cannot be the result of the distance the Earth is from the sun, "Because think of this. If it was because we're really close to the sun right now, so we're having summer, but doesn't that mean the bottom [the Southern Hemisphere] would be having summer, too, because they're also really close?"

The students responded collectively, "Yeah."

"They're a part of the Earth, too, right? But, do they have summer right now?

"No," they replied.

"So, if it dealt with how close the Earth was, then the whole Earth would be having the same season, but that's not what happens. It deals with the tilt and which part is pointing at the sun."

Mrs. Poppy then explained direct sunlight by holding a pencil to the globe and asking the students to consider how much of the lamp light was cast upon the pencil eraser as she held the globe and revolved around the lamp.

"So, if I'm here in Michigan. This is us…Watch my head. When I'm coming around here and it's sunrise, and I can see that sun a little bit…And now, when I'm right here, it's noon. Where's the sun compared to my head?"

Before students responded, Mrs. Poppy said, "It's above my head, right? Point to above your head. Is that where the sun is at noon?"

Students responded with a variety of responses all at once, so Mrs. Poppy revised her question, "In the summer, is that where the sun is at noon?"

"Yeah," the students responded.

"Yes. Now, it's not perfectly above your head…If I wanted to put it directly above my head, where would I have to be?"

“0 [degrees latitude], lower, Cuba?” a student offered. Several students followed with incorrect responses until Mrs. Poppy explained that direct sunlight is at the Equator.

“If you’re at the Equator or right within this area, it’s directly above your head. Really directly.”

Mrs. Poppy put the pencil on the globe in the area of Michigan and asked again, “So, if I’m standing like this, and the sun is nice and high in the sky at noon, am I getting direct light, though?”

The students responded with another collective, “No,” and Mrs. Poppy validated their response, “No, not getting direct light. It’s pretty strong, but it’s not direct. But, if I’m in Florida, is it a little more direct?”

“Yes!”

“So, what do you know about light if it’s a perfect direct light is it going to be…?

Before Mrs. Poppy could respond, a student chimed in, “Hot,” and Mrs. Poppy agreed, “It’s going to be a lot hotter, right? So even though it’s summer for me in Michigan, it’s also summer in Florida, but they’re going to have a warmer summer because they have more direct light…Does that make sense?

“Yes!”

Mrs. Poppy continued to explain that winter does not always mean snow and cold because some places on Earth always get direct sunlight, “Even though, it’s called winter, it’s still hot.”

The class period ended. Mrs. Poppy reminded the students to clip their worksheets into their science binders. The next day, the students answered the assessment questions on the worksheets.

In this vignette, taken from data collected for this study, we see an instructional focus on understanding science content. Mrs. Poppy presented the same content through various modes–written text, an infographic video, and demonstrations–and asked frequent questions to assist and gauge students' comprehension. The students, however, were mostly passive, which is characteristic of traditional teacher-centered lessons in which information is transferred from one source (i.e., the teacher, the text, the video) to the students (Freire, 1998). We also see a conceptualization of science as a static assemblage of facts to be acquired and retained, a conceptualization for which students need only to apply reading and oral comprehension skills.

In contrast, in the following hypothetical vignette, students are collaboratively engaged in meaningful tasks in which they approximate the disciplinary habits of mind and practices of actual scientists. In this classroom, science is conceived as a body of knowledge and a set of practices for generating, revising, and sharing scientific knowledge, and students employ reading, writing, and language in the service of scientific sense-making. Furthermore, because scientific knowledge is understood to be dynamic, students are expected to use evidence to support their claims about the nature of scientific phenomena.

Mrs. Raymond stopped by a group of students to listen to their nascent understandings for explaining why summers in Florida are warmer than are summers in Michigan. For the past few months, the students in the class had taken weekly turns documenting the daily times for sunset and sunrise, and daily turns for measuring the lengths and directions of their shadows. The students used online resources to obtain the same data for Miami, Florida. Then, they made line graphs of their findings for both locations. That day, the groups were working to identify patterns and consider possible explanations for both the patterns observed at each location and the differences between them.

Listening in on the group, Mrs. Raymond heard one member say that he noticed the daylight hours in Florida are more consistent than they are in Michigan and he thought that maybe the differences were related to the locations' degrees of latitude. They had been learning about longitude and latitude in social studies. One of the group members wrote this potential explanation on chart paper to keep track of their ideas. Another group member shared that she noticed the lengths of shadows were shorter in September than they were in January but did not have an idea for why. Mrs. Raymond asked the group members to brainstorm ideas for how they could test the first student's explanation. She also gave the students a flashlight and encouraged them to share ideas for how they might figure out the conditions that cause a shadow to be shorter or longer. She suggested the students record their ideas or possible models in their science notebooks.

In the hypothetical vignette, we see reform-based instruction designed to develop students' twenty-first century skills (i.e., innovation, problem solving, collaboration) for knowledgeable participation in a democratic society (http://www.p21.org). Embedded in this vision for a literate citizenry is the idea that literacy is multifarious. Different academic fields have different ways of reading, writing, thinking, and reasoning, and thus, one can have multiple literacies. The idea that we should teach these specialized literacies is known as disciplinary literacy (Shanahan & Shanahan, 2014).

According to Fang and Coatum (2013), disciplinary literacy is grounded in four beliefs:

> (a) [S]chool subjects are disciplinary discourses recontextualized for educational purposes;
> (b) disciplines differ not just in content but also in the ways this content is produced, communicated, evaluated, and renovated;
> (c) disciplinary practices such as reading and writing are best learned and taught within each discipline; and

> (d) being literate in a discipline means understanding of both disciplinary content and disciplinary habits of mind (i.e., ways of reading, writing, viewing, speaking, thinking, reasoning, and critiquing). (p. 628)

This understanding of literacy is now the cornerstone of recent science education reforms, such as *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012), the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013), and the Michigan Science Standards (MSS; Michigan Department of Education [MDE], 2015). A disciplinary literacy approach to science represents a conceptual and instructional shift from traditional understandings of what it means to be literate and to do science (Gee, 2015; MDE, 2015). Thus, teachers will need support for enacting instruction that aligns with the demands of the new standards (National Academies of Sciences, Engineering, and Medicine, 2015).

Because meaning is situated (Gee, 2015), diverse settings shape and are shaped by the educational goals, policies, practices, and outcomes of each individual teacher and the students in the classroom. Therefore, the nature of support needed to help teachers meet the new expectations is dependent upon the extent to which current instructional practices reflect, and the educational context in which instruction is enacted supports, the new vision for science education. Thus, the goal of this dissertation is to explore how context-specific pedagogical resources and constraints shape instructional practices in an elementary teacher's fifth grade science class and the extent to which those practices align with a disciplinary literacy approach to science.

The remainder of this chapter provides a description of the problem space for this study and overviews of the research design, the significance, and the forthcoming chapters.

Background of Problem

In the past two decades, much educational reform in Michigan has focused on reading instruction and student reading proficiency. These reform efforts have created many programs and plans for increasing reading proficiency across the state, but they have also had an effect on science instruction. Current science instruction, shaped to adhere to the literacy reforms, poses potential challenges for teachers who are now charged with implementing new science standards. In this section, I describe the literacy and science reforms of the past 20 years and their combined impact on current science instruction.

Two Decades of Reforms Emphasizing Elementary Reading Instruction Affected Science Instruction

In 2000, Michigan initiated a multi-tier system of support (MTSS) program with the premise that improved reading achievement would correlate with lower incidents of student misbehavior. To achieve at least 80 percent of students reading at school proficiency levels, the program mandated 90 minutes of uninterrupted reading instruction per day with a focus on the "big ideas" of reading: phonemic awareness, alphabetic principle, fluency, vocabulary, and comprehension. According to the program, the reading block should not include other elements of literacy, such as handwriting, grammar, the writing process, or keyboarding (miblsi.org). The program was only available in some districts at the time, but since then, the 90-minute (and 90+ minutes) block has become commonplace due to additional policies and programs, such as the *No Child Left Behind Act of 2001* (No Child Left Behind [NCLB], 2002).

In 2002, NCLB mandated yearly reading and mathematics assessments for all students in Grades 3 through 5. These assessments were used, in part, to determine a school's yearly progress in raising student achievement. Failure to meet adequate yearly progress (AYP) had important repercussions, such as loss of funding, state control of the district, or mandatory remedial services. This legislation, as the first national law to impose consequences for student performance, changed the way many schools allotted instructional time. For example, in 2007, the Center for Education Policy published a report on the state of instruction and curriculum after five years under NCLB (McMurrer, 2007). The report was based on a nationally representative survey of 349 responding school districts and showed that following the enactment of NCLB, 58% of responding districts increased instructional time for elementary ELA instruction and 45% increased time for mathematics. In the 2006-2007 school year, elementary schools scheduled three times as many minutes per week for ELA as for science and social studies and two times as much for math.

In 2010, Michigan adopted the *Common Core State Standards* (CCSS; National Governors Association Center for Best Practices, Council of Chief State School Officers [CCSSO], 2010) for ELA and math and drafted the Michigan Statewide Comprehensive Literacy Plan (MiLit Plan). The MiLit Plan called for districts to align their instruction with the CCSS and to develop district literacy plans in which the district described its methods for implementing highly effective literacy instruction and using literacy assessments and diagnostics. The district plan was also to detail an MTSS, which commonly recommends a two-hour reading block for Tier 1 instruction (Campsen, 2013, para. 2).

In 2011, the stakes were raised on student achievement by tying student growth, as measured by state standardized assessments, to teacher effectiveness (Michigan Assessment Consortium, 2018). Currently, state assessments only report elementary student achievement for English Language Arts (ELA) and mathematics (Grades 3-7) and fifth grade social studies (This will change this year to include fifth grade science.). With teachers' employment partially dependent upon how well their students can perform on ELA and math assessments, teachers and schools prioritized ELA and math instruction, often at a cost to science instruction.

First, little classroom time is allotted for science instruction. According to the most recent National Survey of Science and Mathematics Education [NSSME+] (Banilower et al., 2018), elementary teachers in Grades 4-6 spend an average of 82 minutes and 63 minutes per day on reading and math instruction, respectively, yet only 27 minutes per day on science instruction. Secondly, the little time dedicated to science is often spent reading and discussing science texts (Banilower et al., 2018; Barber, 2019) To help students access the science texts, teachers provide explicit instruction in generic reading skills and strategies, an instructional practice known as content-area literacy (Barber, 2019; Cervetti & Pearson, 2012; Chauvin & Theodore, 2015; Fang & Coatum, 2013; Moore, Readence, & Rickelman, 1983). Content-area literacy (CAL) mediates the high instructional demands for ELA with those for teaching science. Moreover, the approach aligned well with the state's standards for science and ELA. In the next section, I describe the congruence between the demands of these two sets of standards and CAL as a pedagogical approach for meeting them.

Content-Area Literacy a Match for the GLCEs for Science and the CCSS for ELA

Content-area literacy is a pedagogical approach centered on strategies for supporting students in reading and writing content area texts (Moore, Readence, & Rickelman, 1983; Moss, 2005). This approach aligned well with the state standards for science, which focused on understanding content, and the state standards for ELA, which call for cross-disciplinary and informational text reading. In this section, I describe those standards and CAL as appropriate for meeting them.

In 2007, Michigan adopted the Grade Level Content Expectations for Science (GLCEs; MDE, 2007). The GLCEs were organized by discipline and by grade level. In the GLCEs, there were four disciplines: science processes, physical science, Earth science, and life science. Each discipline had at least one standard for K-7. Table 1.1 contains the standards for two disciplines, science processes and Earth science.

Table 1.1
GLCEs for Science Processes and Earth Science

<table>
<tr><th>Standards for Science Processes</th><th>Standards for Earth Science</th></tr>
<tr><td>Develop an understanding that scientific inquiry and reasoning involves observing, questioning, investigating, recording, and developing solutions to problems.</td><td>Develop an understanding of the warming of the Earth by the sun as a major source of energy for phenomenon on Earth and how the sun's warming relates to weather, climate, seasons, and the water cycle. Understand how human interaction and use of natural resources affect the environment.</td></tr>
<tr><td>Develop an understanding that scientific inquiry and investigations require analysis and communication of findings, using appropriate technology.</td><td rowspan="2">Develop an understanding that the sun is the central and largest body in the solar system and that Earth and other objects in the sky move in a regular and predictable motion around the sun. Understand that those motions explain the day, year, moon phases, eclipses and the appearance of motion of objects across the sky. Understand that gravity is the force that keeps the planets in orbit around the sun and governs motion in the solar system. Develop an understanding that fossils and layers of Earth provide evidence of the history of Earth's life forms, changes over long periods of time, and theories regarding Earth's history and continental drift.</td></tr>
<tr><td>Develop an understanding that claims and evidence for their scientific merit should be analyzed. Understand how scientists decide what constitutes scientific knowledge. Develop an understanding of the importance of reflection on scientific knowledge and its application to new situations to better understand the role of science in society and technology.</td></tr>
</table>

As Table 1.1 shows, the standards called for students to "develop an understanding" and "understand." According to Anderson et al. (2001), understanding is a product of comprehension, which the National Reading Panel defines as the construction of meaning through interaction with texts (Eunice Kennedy Shriver National Institute of Child Health and Human Development, 2000, p. 14). Therefore, a reasonable interpretation of the goal for the science GLCEs was that students should learn to read texts and understand science content.

Decidedly, in 2010, when the CCSS (CCSSO, 2010) for ELA were adopted, this interpretation aligned well with the CCSS.

The CCSS for ELA "define general, cross-disciplinary literacy expectations" (CCSSO, 2010, "Introduction," para. 1) designed to help students become college and career ready by the conclusion of high school. But, standards are variously interpreted (Ball & Cohen, 1996) and thus, according to Dickinson and Young (1998), "cross-disciplinary" has had many meanings. In elementary school, cross-disciplinary usually means embedding literacy skills into content learning. An example of this is a lesson called "RAFTing with Raptors" created by the University of South Carolina's Writing Project (Senn, McMurtie, & Coleman, 2013), specifically to meet CCSS for ELA and "focus on science literacy" (p. 53). After reading bird field guides and visiting a raptor center, students are tasked with demonstrating their understanding through creative writing using RAFT. RAFT is a writing strategy for which students choose a Role, such as writing from the perspective of an owl pellet or a tree branch, an Audience, such as a mouse or a logger, a Format, such as an obituary or a want ad, and a Topic, such as "why I'm important to you" and "I like to get my nails done" (pp. 53-55). The lesson's creators explain that this lesson is a way to fulfill the demands for ELA instruction by offering a way to employ ELA strategies for learning content.

Further, the CCSS (CCSSO, 2010) for elementary ELA demand that students spend equal amounts of time with informational texts as with fictional narratives. Informational texts, however, pose another challenge because they are information-dense, use abstract language and technical vocabulary, and are presented in an authoritative tone (Fang, 2005). Indeed, many teachers report students' struggles to understand content-area texts as one of the biggest challenges to learning (Chauvin & Theodore, 2015). To remedy this issue, teachers embraced materials such as *Do I Really Have to Teach Reading?* (Tovani, 2004) and *Content Area Writing: Every Teacher's Guide* (Daniels, Zemelman, & Steineke, 2007) which promoted the use of generic comprehension and writing strategies for supporting students' understanding of content-area texts, or content-area literacy.

Together, these two sets of standards, the GLCEs (MDE, 2007) for science and the CCSS (CCSSO, 2010) for ELA reasonably suggested that science instruction could be met by reading science texts (see Table 1.2, using 5th grade standards).

Table 1.2
Congruency of GLCEs and CCSS

<table>
<tr><th>GLCE for 5th Grade Science</th><th>CCSS for 5th Grade
Reading: Informational Text</th></tr>
<tr><td>P.FM: Develop an understanding that the position and/or motion of an object is relative to a point of reference. Understand forces affect the motion and speed of an object and that the net force of an object is the total of all of the forces acting on it. Understand the Earth pulls down on objects with a force called gravity. Develop an understanding that some forces are in direct contact with objects, while other forces are not in direct contact with objects.</td><td rowspan="3">CCSS.ELA-LITERACY.RI.5.2 Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.

CCSS.ELA-LITERACY.RI.5.3 Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.

CCSS.ELA-LITERACY.RI.5.4 Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a *grade 5 topic or subject area*.

CCSS.ELA-LITERACY.RI.5.5 Compare the overall structure of events, ideas, concepts, or information in two or more texts.

CCSS.ELA-LITERACY.RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.

CCSS.ELA-LITERACY.RI.5.8 Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s).</td></tr>
<tr><td>L.OL: Develop an understanding that plants and animals (including humans) have basic requirements for maintaining life which include the need for air, water and a source of energy. Understand that all life forms can be classified as producers, consumers, or decomposers as they are all part of a global food chain where food/energy is supplied by plants which need light to produce food/energy. Develop an understanding that plants and animals can be classified by observable traits and physical characteristics. Understand tha[t] all living organisms are composed of cells and they exhibit cell growth and division. Understand that all plants and animals have a definite life cycle, body parts, and systems to perform specific life functions.</td></tr>
<tr><td>L.HE: Develop an understanding that all life forms must reproduce to survive. Understand that characteristics of mature plants and animals may be inherited or acquired and that only inherited traits can be influenced by changes in the environment and by genetics.</td></tr>
</table>

L.EV: Develop an understanding that plants and animals have observable parts and characteristics that help them survive and flourish in their environments. Understand that fossils provide evidence that life forms have changed over time and were influenced by changes in environmental conditions. Understand that life forms either change (evolve) over time or risk extinction due to environmental changes and describe how scientists identify the relatedness of various organisms based on similarities in anatomical features.	CCSS.ELA-LITERACY.RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. CCSS.ELA-LITERACY.RI.5.10 By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grade 4-5 text complexity band independently and proficiently.
E.ES: Develop an understanding of the warming of the Earth by the sun as a major source of energy for phenomenon on Earth and how the sun's warming relates to weather, climate, seasons, and the water cycle. Understand how human interaction and use of natural resources affects the environment.	
E.ST: Develop an understanding that the sun is the central and largest body in the solar system and that Earth and other objects in the sky move in a regular and predictable motion around the sun. Understand that those motions explain the day, year, moon phases, eclipses and the appearance of motion of objects across the sky. Understand that gravity is the force that keeps the planets in orbit around the sun and governs motion in the solar system. Develop an understanding that fossils and layers of Earth provide evidence of the history of Earth's life forms, changes over long periods of time, and theories regarding Earth's history and continental drift.	

Table 1.2 shows that most of the fifth grade CCSS (CCSSO, 2010) for informational texts, if applied to texts that correspond with the science content (GLCE standards), would fulfill both science and informational reading goals. For example, in her book, *Reading Science: Practical Strategies for Integrating Instruction,* Jennifer L. Altieri (2016) offers many generic strategies for reading science texts, such as prereading for unfamiliar vocabulary words, using T-charts to compare information from sources, and annotating texts with symbols. When used while reading a field guide about birds, for example, these strategies contribute to the goal of reading and comprehending science texts independently (CCSS.ELA.LITERACY.RI.5.10) and understanding that animals have observable characteristics that help them to survive (GLCE.L.EV). If combined with a task, such as the RAFT lesson above (Senn, McMurtie, &

Coleman, 2013), or writing an acrostic poem about the animals (i.e., Frye, Trathen, & Schlagal, 2010) additional standards are fulfilled, such as integrating information from multiple sources to write about a topic (CCSS.ELA-LITERACY.RI.5.9).

CAL helped teachers to bolster reading comprehension instruction–the aim for the literacy reforms, read informational texts–a requirement of the CCSS, and understand science content–the goal of the GLCEs. However, because Michigan has now replaced the GLCEs with new science standards that call for engaging students in disciplinary literacy practices, a CAL approach to science instruction is no longer sufficient. In the next section, I explain the new standards.

New Standards: New Ways of Doing Science

In 2012, the National Research Council (NRC) published *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012; hereafter referred to as the *Framework*), which articulates a vision for science education in which students actively engage in scientific practices and apply crosscutting concepts in the context of understanding disciplinary-based core ideas. The *Framework* served as a guide for the development of the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013). The NGSS are student performance expectations that specify, by grade level, the knowledge and practices necessary for students to become disciplinary literate by the end of high school. In 2015, Michigan adopted the NGSS standards as the Michigan Science Standards (MSS; Michigan Department of Education [MDE], 2015). The MSS mirror the NGSS with the addition of Michigan-specific performance expectations in second, fourth, and fifth grades.

The MSS are arranged by grade level and then by topics. Within each topic are three or four standards. For example, in fifth grade, there are 16 standards within 5 topics: Structure and

Properties of Matter (4); Matter and Energy in Organisms and Ecosystems (3); Earth's Systems (3); Space Systems: Stars and the Solar System (3); and Engineering Design (3).

In accordance with the *Framework* (National Research Council, 2012) and the NGSS (NGSS Lead States, 2013), the MSS (MDE, 2015) call for students to engage in science at the intersection of three dimensions: science practices (processes), crosscutting concepts (unifying themes), and core ideas (content) (see Appendix A); the nexus of these three dimensions encompasses disciplinary literacy in science (Houseal, Gillis, Helmsing, & Hutchison, 2016). The first dimension, science practices, reflects the actual work of scientists and describes what it means to "do science." These eight practices (see Figure 1.1) support the generation and revision of scientific knowledge.

Figure 1.1
Screenshot of 3 Dimension 1: Scientific and Engineering Practices (National Research Council, 2012, p. 42)

BOX 3-1

PRACTICES FOR K-12 SCIENCE CLASSROOMS

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The second dimension describes the scientific concepts that transcend science disciplines: patterns; cause and effect; scale, proportion, and quantity; systems and systems models; energy and matter: flows, cycles, and conservation; structure and function; and stability and change.

These crosscutting concepts create a coherent scientific understanding of phenomena and are found in all areas of science. The third dimension, core ideas, “prepare[s] students with sufficient core knowledge so that they can later acquire additional information on their own” (National Research Council, 2012, p. 31). The core ideas help students to be producers and critical consumers of scientific information.

The hypothetical vignette at the beginning of this chapter helps us to see how these three dimensions work in tandem to help students make sense of natural phenomena. In Mrs. Raymond’s hypothetical fifth grade, the project objective was to prepare students to meet the standard, “Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky” (MDE, 2015, p. 19). Specifically, this standard requires students to engage in Practice 4: Analyzing and interpreting data to make sense of celestial patterns (the crosscutting concept) related to Earth’s rotation, revolution, and tilt (core ideas). In the process of meeting this expectation, students also obtained information (Practice 8) by collecting observational data and analyzed and interpreted data (Practice 4) by organizing the information into graphs and looking for patterns. They were also in the beginning stages of developing models (Practice 2) for conceptualizing their current explanations (Practice 6) for the relationship between hours of daylight and a location’s latitude. In addition, they were working collaboratively, a component of Practice 8.

The MSS (MDE, 2015) require a paradigm shift in how teachers and students conceptualize and engage in science. In the past, science has been thought of as a body of knowledge attainable by reading texts. The MSS present science as a culture of practice (Shanahan & Shanahan, 2014) that is both a body of knowledge and a set of practices. Therefore, in order for teachers to enact instruction that aligns with the new vision for science teaching, they will need support for understanding and engaging students in the practices, concepts, and core ideas that are inherent in doing science. The type and extent of that support depends on teachers' instructional contexts. This study explores the resources of constraints of one teacher's instructional context prior to her school's adoption of the MSS (MDE, 2015).

Supporting Teachers in Making Instructional Change Requires Knowledge of Context

Moving from the current approach to science instruction to an approach that foregrounds the practices of scientists cannot be achieved simply by changing standards. Teachers' instructional practices shape and are shaped by their contexts (Ball & Cohen, 1996; Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005; National Academies of Sciences, Engineering, and Medicine, 2015). Specifically, enacted instruction is influenced by and influences what teachers think about their students' familiarity, potential, and struggles with the content and tasks presented; their own understandings of the content and pedagogy; their available materials and instructional resources; the intellectual and social dynamics of the class; and institutional and community expectations and policies (Ball & Cohen, 1996).

Thus, understanding the potential for teachers to adopt a disciplinary understanding of science and to adapt their instructional practices accordingly requires understanding their instructional contexts. The goal of this dissertation is to inquire deeply into one teacher's context and practices to explore the extent to which they align with a disciplinary approach.

Statement of Purpose and Research Question

Michigan's new science standards, the Michigan Science Standards (MSS; MDE, 2015) call for instruction in disciplinary literacy, tasking teachers with understanding, or becoming literate in, and teaching the practices and habits of mind inherent in engaging in science disciplines. The new standards are markedly different from the previous standards, and therefore, teachers will need help to enact instruction consistent with the new standards. According to the National Academies of Sciences, Engineering, and Medicine (2015), helping teachers to bridge the differences between current instruction and the new way of teaching science will require attending to teachers' individual, context-specific needs (pp. 4-6). The purpose of this case study is to explore the context-specific needs of an elementary teacher in the teaching of fifth grade science. The research question guiding this inquiry is *How do pedagogical resources and constraints shape a teacher's instructional practices in the teaching of elementary science, and to what extent do these practices conform with a disciplinary approach to science?*

Research Approach

This qualitative, microethnographic (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005; Spradley, 2009) research is a common case study (Yin, 2014) of one elementary teacher's practices in the teaching of two units of science. Common case study research is a deep investigation into the circumstances of an everyday situation (Yin, 2014), science instruction, within its natural context, the elementary classroom, through the collection of data from multiple sources and several different methods. For this study I collected data from two main sources, an interview with the participating teacher and classroom observations. From these two sources, I have audio recordings, detailed field notes, classroom artifacts, and digital photographs.

Consistent with microethnographic and case study research, I treat the boundaries between the context and the phenomenon as indistinct. In the elementary science class, the teacher, the learners, the content, and the environment interact (Cohen, Raudenbush, & Ball, 2003) and through those interactions construct both the conditions under which instructional practices are enacted and the instructional practices. Linda Darling-Hammond (2006) describes this inseparable nature of teaching and context:

> [R]ecent research has made it clear that all teaching and all learning are shaped by the context in which they occur – by the nature of the subject matter, the goals of instruction, the individual experiences, interests, and understandings of learners and teachers, and the settings within which teaching and learning take place. (115)

In other words, instruction is a conglomerate of personal (i.e., the teacher's knowledge and preparation), local (i.e., school schedules and curricula), and institutional (i.e., policies, reforms, and standards) dynamics and influences. In turn, instruction shapes the context as ideas and communities evolve from it.

Significance of Study

Historically, reforms designed to transform teaching from rote, teacher-centered instruction to progressive student-centered instruction have had varied levels of success (Cohen, 2011; Cuban, 2013; Loeb, Knapp, Elfers, 2008). Plentiful research juxtaposes teachers' enacted instruction with the instructional ideals of reform efforts to determine the extent to which teachers' instruction aligns with reform-based instruction (e.g., Bismack, Arias, Davis, & Palincsar, 2014; Brezicha, Bergmark, & Mitra, 2015; Charalambous, Hill, & Mitchell, 2012; Cohen, 1990; Concannon-Gibney & McCarthy, 2012; Glen & Dotger, 2013; Remillard & Bryans, 2004; Roychoudhury & Rice, 2010; Vo, Forbes, Zangori, & Schwarz, 2015). The discrepancies and continuities are frequently explained by mediating effects of the instructional context. While this information is valuable and establishes the strong interdependent relationship between context and instruction (Ball & Cohen, 1996; Bloome et al., 2005), little research attends to the capacity of specific contexts to support reform-based instruction prior to the roll-out of reforms. This study addresses a need for assessing the compatibility of existing instructional contexts by studying the liminal space between fifth grade science instruction aligned with the GLCEs (MDE, 2007) and that intended by the MSS (MDE, 2015).

Furthermore, in Michigan, the annual teacher evaluation process requires teachers to set individual performance goals for improving their instruction. Currently, though, teacher professional learning opportunities are most likely to be one-size-fits-all professional development models focused on skills assumed to be widely applicable. The findings of this study support the growing body of research literature calling for differentiated professional learning, or professional learning that addresses teachers' individual weaknesses and capitalizes on their strengths relative to their instructional contexts (Chard, 2004; Hill, 2009; National Academies of Sciences, Engineering, and Medicine, 2015) and proposes a process for scaffolding current instructional practices toward reform-based practices.

Organization of the Dissertation

In Chapter 2, I develop the conceptual framework for this dissertation establishing disciplinary literacy for science instruction as a paradigm shift that will require significant conceptual and instructional changes to teacher practice, context as a mediator for enacting instruction congruent with reform ideals, and the need for attending to the capacity of instructional contexts to support future reform ideals. Chapter 3 describes the context, the participants, and the data collection and analytic methodology I employed to iteratively analyze the observation and interview data from a range of analytic perspectives.

In Chapter 4, I show how this analysis reveals the conceptualizations of science presented by the resources and constraints of the participating teacher's instructional context and how these conceptualizations are manifested in instructional practices. I describe the extent to which these instructional practices conform with the disciplinary literacy approach to science called for in the Michigan Science Standards (MDE, 2015).

Chapter 5 describes the conceptual process through which I identified instructional scaffolds for leveraging current instructional practices in transitioning to reform-based instructional practices. I present this process as a potential model for designing differentiated professional learning. Finally, I synthesize the findings, putting them into conversation with recent literature, and present the implications and limitations of this research.

CHAPTER II

Review of Literature

The *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013), adopted in Michigan as the Michigan Science Standards (MSS; Michigan Department of Education [MDE], 2015) are based on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012), which calls for science instruction in which students use knowledge of, and generate scientific ideas through, authentic scientific practices. This disciplinary literacy approach to science instruction acknowledges that reading, writing, and using language are integral to scientific practice (Hand et al., 2003; Yore, Florence, Pearson, & Weaver, 2006). This new vision for science education represents a paradigm shift in how science is understood, taught, and learned.

In the past, reforms similar to the NGSS and the MSS designed to change how teachers teach and what students do have resulted in only modest modifications in instructional practice (Cohen, 2011; Cuban, 2013; Fenstermacher & Richardson, 2005; Kennedy, 2005; Payne, 2008). Studies exploring the reasons reforms have not effected widespread and substantial change point to the complex (Cuban, 2013), fragmented (Cohen, 2011) systems in which classrooms exist and to the resources and constraints of individual classroom contexts that shape how reforms are actualized. In this chapter I review what is known about the role of context in the implementation of reform-based practices. I argue that despite the plethora of research in this area, few studies explore the liminal space between current instructional practice and upcoming reforms and the extent to which contextual resources and constraints are compatible with reform expectations. This knowledge is essential for discerning the nature of support necessary for teachers within specific contexts to begin implementing instruction aligned with the demands of new reforms. Let me begin by exploring the paradigm shift.

The Paradigm Shift from Content-Area Literacy to Disciplinary Literacy Instruction

As described in the first chapter, a disciplinary literacy approach to science education is a conceptual and instructional shift from the previous standards and their associated instructional practices. The previous pedagogical approach to science instruction, Content-Area Literacy (CAL) instruction is insufficient for meeting the disciplinary literacy demands of the NGSS and MSS. In this section, I describe the theoretical perspectives undergirding disciplinary literacy, distinguish between CAL and disciplinary literacy, and review the expectations for disciplinary literacy in science.

The Sociocultural Foundations and Implications of Disciplinary Literacy

Disciplinary literacy is based on sociocultural theories of language (Gee 2001, 2004, 2015; Schleppegrell, 2004) that posit that literacy practices are used in particular ways in particular contexts. This conception of literacy contrasts with the traditional understanding of literacy as the ability to read and write. In this section, I describe the theoretical foundation of disciplinary literacy.

Theoretical Understanding of Disciplinary Literacy

According to Gee (2015), “We are all multiple kinds of people” (p. 173) because we assume different identities and participate in a variety of activities based on our contexts. In each context, we establish who we are–what socially-situated identity we are assuming–and what we are doing–what socially-situated activity we are engaged in (p. 172).

Likewise, all language is situated (Gee, 2004, 2015; Halliday, 1994); words and deeds have specific meanings and purposes relative to the context in which they are shared. For example, the word *meter* brings different images in the context of a literature class than it does in a science or mathematics class. Therefore, English is not just one general language; it is comprised of many different socially-constructed languages known as *social languages* (Gee, 2015, p. 101). Social languages are the unique ways with oral and written words that make manifest socially-situated identities and activities of a community of practice (Gee, 2004). They are intrinsically tied to the *doing* (Gee, 2001). For example, someone who identifies as a Catholic parishioner must know the words of the responses as well as the cadence with which they are recited at a service.

When members of the community of practice are able to produce and consume the social language, they are then recognized as socialized into what Gee (2015) calls a “Discourse with a capital ‘D’” (p. 172). Discourses include social languages as well as the habits of mind and cultural tools that are characteristic of the community, as Gee (2015) explains,

> Being in a Discourse is being able to engage in a particular sort of ‘dance’ with words, deeds, values, feelings, other people, objects, tools, technologies, places and times so as to get recognised as a distinctive *who* doing a distinctive sort of *what.* Being able to understand a Discourse is being able to recognise such ‘dances.’ (p. 172)

Disciplines, such as science, are Discourses, with their own unique ways for using language and participating in the practices that define the Discourse. This perspective is the basis for disciplinary literacy. To be literate in the Discourse of science requires understanding the specialized language and norms of participation inherent in doing science.

Differences Between Content-Area Literacy and Disciplinary Literacy

A common misconception is that disciplinary literacy is synonymous with content-area literacy (Shanahan & Shanahan, 2012). In this section I describe content-area literacy and the problematic nature of applying "content-free" (Cervetti & Pearson, 2012, p. 582) strategies in disciplinary studies. Then, I describe the disciplinary literacy expectations of the new standards.

Metacognitive Studies, Strategy Instruction, and Content-Area Literacy

In 1978, the National Institute of Education [NIE] requested the creation of a center for studying best practices in reading instruction. The NIE based its request on three assumptions: reading comprehension can be taught, it is being taught, but it is not being taught well (Durkin, 1978-1979). Dolores Durkin, who identified herself as "a veteran observer of elementary classrooms" (p. 483) was surprised by the assumption reading comprehension was being taught, so she conducted a study to determine the prevalence and foci of comprehension instruction. The study was comprised of sub-studies. For the first sub-study, she observed fourth grade reading and social studies instruction in 24 classrooms from 13 school systems, and in the second those subjects in 3-6 grades in 4 classrooms from 3 schools. The third sub-study involved observations of three students, one child from each Grade 3, 5, and 6. She found that there was no comprehension instruction occurring in classrooms except to assess student comprehension through interrogation. Reading instruction largely involved phonics, word analysis, definitions, and assignments (Durkin 1978-1979).

Despite these results, Durkin's study prompted additional research into how to best support students' independent comprehension abilities. This line of research focused on metacognition, or "the process of thinking about one's own thinking" (Tracey & Morrow, 2012, p. 71). Metacognition studies indicated that good readers use a variety of metacognitive strategies to aid their reading comprehension.

Good readers activate their relevant background knowledge to make connections between old and new information and make inferences. They ask themselves clarifying questions when they do not understand and have a metacognitive toolkit of strategies for remedying confusion. Good readers summarize by separating main ideas and details and synthesize their thinking. They also use sensory images to enhance understanding (Tovani, 2004, p. 5).

By identifying what good readers do, teachers can help struggling readers to make sense of texts by teaching them how to use the metacognitive strategies that support the reading comprehension of good readers. Strategy instruction is taught through a gradual release of responsibility model in which the teacher provides explicit instruction in how and when to use a strategy, models the strategy in use, and gradually helps students to assume responsibility for using the strategy independently (Duke & Pearson, 2002). Teachers who are well-prepared to teach strategy instruction in this way have a positive effect on student reading comprehension (Eunice Kennedy Shriver National Institute of Child Health and Human Development, 2000).

Content-area literacy instruction applies the tenets of strategy instruction to the content areas. The premise of content-area literacy instruction is teachers can help students to access complex, content-area texts, such as science texts, by using literacy strategies to support comprehension (Moore, Readence, & Rickelman, 1983; Moss, 2005). For example, content-area literacy instruction assumes that vocabulary learning is the same across school subjects (Shanahan & Shanahan, 2012), and therefore strategies for understanding vocabulary area are universally applicable. One strategy for helping students remember and understand vocabulary words is creating vocabulary cards using the Frayer Model (Fisher, Brozo, Frey, & Ivey, 2011). This before reading strategy requires students to divide a card into quadrants and put specific information in each box: the definition, characteristics or a description of the vocabulary word, examples of the word, and nonexamples. According to Fisher et al., (2011), this vocabulary routine helps students by relating what they do not yet know to what they do know and it requires students to interact with the words for a longer period of time thereby improving memory (p. 135). This strategy seems less useful for words like *photosynthesis*, *tectonic plate*, and *Asteroid Belt* than for words like *amorous, strutted,* or even *parallelogram.* Shanahan and Shanahan (2012) assert that what would be helpful for helping students to learn science words, for example, would be to analyze the Greek and Latin roots because science words are purposely constructed with these derivatives, so as to "offer a more complete and precise description of concepts than is possible with vernacular terms" and to make the words "more resistant to meaning changes and to the morphological shifts that occur across time and across languages" (p. 9). Shanahan and Shanahan (2012), of course, are advocating for a disciplinary literacy approach to vocabulary instruction.

Disciplinary Literacy in Three Dimensions

As mentioned in the first chapter, according to the *Framework* (National Research Council, 2012), disciplinary literacy is realized at the intersection of three dimensions: practices (disciplinary processes), crosscutting concepts (big ideas), and core ideas (content). In this section I provide a brief overview of each of these dimensions.

The eight scientific practices (Appendix A) refer to the processes that construct scientific knowledge. The *Framework* (National Research Council, 2012) claims that the focus on scientific practices contributes to better conceptualizations of science by extinguishing the mistaken notions that the work of scientists can be reduced to a set of linear steps, commonly referred to as "The Scientific Method," and that all scientists use a universal approach. Below I list the practices and their overall intent:

- Asking questions about a phenomenon: Students should have experience formulating questions that can be answered empirically.
- Developing and using models: Students should use physical and conceptual models to help them develop explanations about phenomena.
- Planning and carrying out investigations: Students should carry out investigations for which they have carefully planned the data to be collected, the measures and levels of accuracy, and variables, if necessary.
- Analyzing and interpreting data: Students should organize data into graphical representations to derive meaning from data.
- Using mathematics and computational thinking: Students should use tools from math and computation to collect and analyze data.
- Constructing explanations: Students should construct and propose hypotheses, which are probable explanations for phenomena.
- Engaging in argument from evidence. Argumentation is an integral practice for advancing scientific work (Palincsar, 2013, p. 11), and students should have experience with reasoning, collecting evidence, presenting and supporting claims, and critiquing.
- Obtaining, evaluating, and communicating information: Students should communicate their scientific arguments and findings and engage in thoughtful critique.

As evident, reading, writing, speaking, thinking, and reasoning are embedded in these practices.

The crosscutting concepts refer to the ways scientists organize ideas. Two of these crosscutting concepts are "fundamental to the nature of science" (National Research Council, 2012, p. 84): observed patterns can be explained and science seeks to explain cause-and-effect relationships. Additional crosscutting concepts include: scale, proportion, and quantity; systems and systems models, energy and matter: flow, cycles, and conservation; structure and function; and stability and change.

Finally, the core ideas–matter and its interactions, stability: forces and interactions, energy, and waves and their applications in technologies for information transfer answer broad questions inherent in scientific work: *What is everything made of?* and *Why do things happen?*

Disciplinary literacy instruction presents these dimensions as intricately woven, and that to unwind them is to suggest that science is either about content or about practices rather than an interplay of both. This understanding of science, reflected in the new science standards, drastically changes expectations for how science is taught and learned, representing a paradigm shift in science education.

Historically, reform efforts aimed at conceptual and instructional change have had varied levels of success (Cuban, 2013; Cohen, 2011; Judson, Ernzen, Krause, Middleton, & Culbertson, 2016, Payne, 2008). Research examining the differences in reform implementation suggests that contextual resources and constraints of individual classrooms in which teachers teach mitigate the effectiveness of instruction. In the next section, I explore what is known about how instruction shapes and is shaped by context.

The Interplay of Instruction and Context

All educational reforms center on teaching (Shulman, 1992). However, according to Shulman (1992) measures of reform that attend only to observable teaching performance neglect "other critical aspects of teaching" (p. 14). Cuban (2013) argues that learning is the sum of classroom environment and events, the school setting, and teacher quality. Fenstermacher and Richardson (2005) concur that the actions of the teacher are but one element necessary for successful teaching: "For teaching to be both good and successful, it must be conjoined with factors well beyond the range of control of the classroom teacher" (p. 186). Specifically, they argue that in addition to good teaching, successful teaching is dependent upon willing and effortful learners, supportive environments, and opportunities for teaching and learning (p. 190). Kennedy (2005) asserts that teachers are aware of the intentions and goals of reforms, but those ideals are among many factors dictating instruction. She found that classroom events and "routine conditions of classroom life" (p. 2)–materials, time, students, student ideas, accessibility, and disruptions, for example–are the real drivers of instructional practice. In sum, these scholars acknowledge the important role of context in realizing reform-based teaching.

In this section, I explore the interplay of context and instruction. First, I present the theoretical perspective that guides my understanding of the relationship between context and instruction. Then, I present examples from research that show the challenges teachers face in enacting reform-based practices that are incoherent with their instructional contexts. Finally, I make the case for proactive inquiries into the liminal space between existing instruction and reform-based practices.

Implied Personhood and Foregrounding Events

Classrooms contexts construct and are constructed by interactions. This theoretical perspective is based on two tenets, implied personhood and the foregrounding of events (Bloome et al., 2005). Personhood is socially constructed and includes the characteristics that are assumed to define a person. Bloome et al. (2005) foreground three aspects of personhood for the study of classroom events. First, people are agentive and resist feeling out of control. They intentionally negotiate their personhood by grappling with meanings, relationships, and ideas. Second, people are situated; they influence and are influenced by their contexts. Third, people and what they do are indistinguishable boundaries, for example a teacher teaches.

Foregrounding events means focusing on the social events of a classroom. A social event is a theoretical construct for "making an inquiry into how people create meaning through how they act and react to each other" (Bloome et al., 2005, "Focusing on Events," para. 1). This notion is explained through several understandings of events. One, people act and react to each other in various ways and in response to actions happening in the present, to previous actions, or to future actions. Two, reactions and actions are not necessarily simultaneous, but they can be, and the reactions and actions might manifest from a sequence of actions or an individual action. Finally, meaning and significance reside in the actions and reactions people share.

According to Bloome et al. (2005), in the classroom, these two elements mean that

> Together teachers and students address the circumstances in which they find themselves, and together they construct their classroom worlds. They often do so with creativity, adapting the cultural practices and social structures thrust on them in ways that may undercut or eschew the ideological agenda of the broader social institutions within which classrooms are embedded. (Chapter 1, para. 4)

This perspective forms the foundation for this dissertation; to understand the teacher's instruction, I must also understand the context in which she teaches.

The Challenge of Incoherence Between Context and Reform-Based Interventions

Instruction is situated (Remillard & Heck, 2014) and jointly and reciprocally shaped by "teachers, students, and materials in particular contexts" (Ball & Cohen, 1996, p. 7). Teachers enact instruction across five contextual domains: what they think to be true about their students' ideas, aptitudes, and learning; their own understandings of material and content; their resources and requirements for lessons; the intellectual and social environment of the class; and broader community and policy contexts in which teachers work (Ball & Cohen, 1996). In this section, I explore the relationship between context and reform efforts, specifically highlighting research demonstrating the challenge of realizing reform ideals when associated practices do not cohere with existing resources and constraints of specific contexts.

Teachers' prior experiences; beliefs about curriculum, instruction, and students; and their understanding of materials and standards influence their instructional practices (Ball & Cohen, 1996; Glen & Dotger, 2013; Judson et al., 2016; Vo, Forbes, Zangori, & Schwarz, 2015). An iconic case study by Cohen (1990), describes the discontinuities between the goals of a new progressive mathematics reform in the state of California and the mathematical knowledge of an early elementary teacher, Mrs. Oublier. Mrs. O held a traditional understanding of mathematics as a static body of knowledge while the reform centered mathematics teaching and learning on conceptual ideas and explanations of mathematical thinking and evidence. Mrs. O attended a workshop and understood the reform's vision for mathematics education and was eager to adapt her instruction and use the new mathematics curriculum and materials. Nonetheless, Mrs. O's pre-existing understanding of mathematics and her limited conceptual knowledge of math allowed for only surface level adaptations to her instruction. For example, Mrs. O engaged the students with new manipulatives, but she facilitated their use in mechanical and algorithmic ways. By refashioning the new instructional practices into her previous, Mrs. O continued to present mathematics as an exercise in right and wrong answers rather than as an act of inquiry, collaboration, and reasoning and evidence, as the reform intended.

Similarly, Roychoudhury and Rice (2010) found that teachers' epistemic science knowledge contributed to the extent to which they could enact pedagogical practices aligned with reform-based science instruction. The study involved 21 elementary teachers from seven urban and 14 suburban schools who were enrolled in a three-credit physical science course as part of a summer institute. The course design was such that the teachers learned through the very practices the instructors hoped the in-service teachers would use to teach their students. The in-service teachers were successful in learning the science objectives for the course (p. 196) yet many did not understand the benefit of taking the pedagogy as an instructional whole. Eight of the 21 in-service teachers indicated via survey responses that they would take up some of the practices embedded in the pedagogy, such as group work or the hands-on activities, but not, for example, practices related to argumentation (pp. 196-197). The researchers speculated that the in-service teachers' "lack of clear understanding of the epistemic facets of the pedagogy indicates that teachers may find it difficult to learn both content and pedagogy at the same time" (p. 200). Roychoudhury and Rice's (2010) and Cohen's (1990) studies, consistent with other research (e.g., Charalambous, Hill, & Mitchell, 2012), show that despite supports for enacting reform-based instruction, teachers without the prior experiences and knowledge of disciplinary science struggle to integrate reform-based instructional practices.

In addition to teachers' ideas and experiences, as part of the instructional context, students and their aptitudes, needs, and understandings also shape (and are shaped by) instruction (Cohen, 2011; Fenstermacher & Richardson, 2005; Kennedy, 2005). Jung, Brown, and Karp (2014) used data from the Early Childhood Longitudinal Study-Kindergarten to examine the relationship between school resources, teacher characteristics, and early mathematics learning. One resource the researchers analyzed was the use of manipulatives for kindergarten mathematics instruction. Manipulatives are commonly associated with reform-based practices for increasing students' conceptual understanding. Analyses indicated that schools that used math manipulatives for kindergarten instruction had significantly higher mean achievement measures at the end of kindergarten than did schools that did not use math manipulatives for instruction. However, for individual students, engagement with manipulatives did not lead to significant progress. Specifically, for students who entered kindergarten with high mathematical abilities, manipulatives were not as beneficial as they were for students who entered kindergarten with little mathematical knowledge. This study indicates that students' diverse achievement levels affect the success of reform-based instructional practices.

Cohen (2011) asserts that the success of reforms is particularly difficult because teachers' efforts can only be successful if their students "strive for and achieve success" (p. 10). Yet, as he explains, students "regularly fear improvement, doubt its possibility, are indifferent, or prefer something other than what [teachers] offer" (p. 11). Students' reluctance to adopt new learning habits and participate productively in learning activities challenged teachers' in Concannon-Gibney and McCarthy's (2012) study efforts to implement reform-based science instruction. The researchers examined how teachers took up knowledge from a professional development seminar on science-literacy integration. Seven elementary and middle school science teachers from Long Island, New York, participated in 12 weekly hour-long workshops to learn how to use the science-literacy integration routine, Do-Read-Do. The workshop instructors taught using Duke and Pearson's (2002) five-step model for the gradual release of responsibility for comprehension development. In doing so, the instructors also intended to model for the teacher attendees how to use this practice in their own classrooms during the "Read" segment of the instructional routine.

The Do-Read-Do routine starts with a brief science investigation, a "do," and is followed by a reading activity. During the reading activity, the teacher uses the gradual release of responsibility model to teach students how to use one of four comprehension strategies: activating prior knowledge, generating questions, clarifying, and using visual summaries (p. 76). The Model's sequence begins with the teacher offering an explicit description of the reading strategy to be used. Next, the teacher models and invites collaborative use of the strategy. Then, students practice using the strategy with teacher guidance. Finally, the students independently use the strategy (p. 75). The Do-Read-Do routine then wraps up; the class uses the knowledge gained from the reading activity to revise the first investigation and carry out the new "do."

The researchers' case study explored the teachers' experiences with implementing the Do-Read-Do routine. In general, the researchers claim the teachers had interest in the new routine and gained confidence with using it over the course of the workshop. Unfortunately, the teachers reported many difficulties with implementing the new routine. One, the teachers found student behaviors to be hindering proper implementation. For some, the collaborative participation structures involved in the routine were too different for students who were not accustomed to working as teams and listening to their peers (p. 82). Other teachers found the activities in the lessons promoted off-task behaviors. Another challenge the teachers encountered was the students' reluctance to participate in the new routine. Specifically, the teachers mentioned the difficulty with trying to get students to restructure their learning habits to spend time thinking about their thinking when using comprehension strategies (p. 83). Moving forward with science instruction in these classrooms likely will require the teachers and students to "negotiate and renegotiate" (Cohen, 2011, p. 11) the goals for science instruction. Those goals might drive instruction that does not adequately resemble the intentions of the Do-Read-Do routine.

As previously mentioned, enacted instruction reflects a plethora of contextual factors that are beyond teachers' control (Fenstermacher & Richardson, 2005; Kennedy, 2005), including schedules, policies, resources, and social capital, and that are not always coherent with reform-based practices. For example, the teachers in Concannon-Gibney and McCarthy's (2012) study felt they did not have enough time in their schedules for using the Read-Do-Read routine with regularity. They reported the lessons took longer than the posited instructional time necessary, state testing interfered, and/or the preparation time was too consuming. These time conflicts meant most teachers only included the Read-Do-Read routine as part of their practices six or seven times over a four-month period.

Similarly, in a study by Bismack, Arias, Davis, and Palincsar (2014) exploring two fourth-grade teachers' use of educative curriculum materials–curriculum materials designed to support teacher learning–for enacting NGSS-aligned (NGSS Lead States, 2013) instruction, teachers cited time constraints as a reason for deviating from the lesson plans. Interview analyses revealed that the teachers found engaging students with science phenomena as described in the curriculum required a great deal of instructional time (p. 506). To compensate for the time demands, teachers either omitted the practice, such as eliminating a field trip around the schoolyard to observe science phenomena, or eliminated other activities in the lesson plans. Typically the eliminated activities involved the scientific practices of constructing arguments and communicating understanding of scientific phenomena, activities found in the final steps of the lesson plans for which teachers had run out of instructional time.

Other research points to the relationship between policy demands and instruction as an obstacle for the enactment of reform-based practices. For example, Remillard and Bryans (2004) conducted a 5-year study on the implementation of a new mathematics curriculum in a small urban elementary school. To support implementation, teachers attended monthly professional development meetings focused on the lessons and concepts as well as educative curriculum materials. Specifically, the materials included "information for the teacher in the form of mathematical explanations, examples of student work and talk, summaries of relevant research, and suggestions for assessment" (p. 357). Yet, because standardized tests required adept computational skills, one of the teachers, Mr. Jackson, used a traditional textbook and focused his lessons on rote algorithmic practice.

School-level policies also inhibit reform-based practices. Several previously mentioned studies (Bismack, et al., 2014; Concannon-Gibney & McCarthy, 2012) described the extensive time required to implement reform-based science instruction, but as mentioned in the first chapter, in response to reading and mathematics expectations, many elementary schools have established rigid reading blocks (Campsen, 2013) and decreased instructional time for science and social studies (Banilower et al., 2018). School policies that limit science instructional time also likely limit the success of reform-based science instruction.

Finally, teachers enact instruction that reflects the accessibility and intensity of their social resources, which foster or limit the success of reform-based practices. According to Cohen (2011) equally adept teachers encounter different risks and opportunities due to their social resources. For example, Brezicha, Bergmark, and Mitra (2015) conducted a 3-year study examining the relationship between school leadership and teachers' understandings of a new school reform to foster civic engagement. The school's principal presented the reform's structure and goals to the teachers and tasked them with working together to design instruction aligned with the goals. Analysis of interview and observational data indicated that teachers' understandings and their subsequent enactments of the civics reform were, in part, reflective of each teacher's social supports. For example, while one of the participating teachers worked closely with the principal and assumed a leadership role in helping other teachers, another teacher expressed frustration that she did not have a "'strong network of peers to rely on for support'" (p. 112) and struggled to design and implement appropriate civics instruction (p. 112).

As evidenced in the Brezicha et al. (2015) study, as part of the instructional context, principals can be a positive or negative social resource for teachers implementing reform-based practices, but a small study by McNeill, Lowenhaupt, and Katsch-Singer (2018) suggests the latter. The researchers interviewed 26 K-8 principals from six districts in an urban area in the Northeastern United States regarding their conceptions of good science instruction. The interview also included video analyses in which principals viewed two short clips of classroom science instruction and described what they noticed about the instruction and how they would evaluate what they saw. Data analyses indicated that the majority of the participating elementary principals were unprepared for leading science reforms and evaluating teachers' reform-based science instruction. When describing "good" science instruction, few principals mentioned the NGSS (NGSS Lead States, 2013) practices related to sensemaking, such as analyzing data, constructing explanations, and developing models, or those related to critiquing, such as constructing arguments. In contrast, the majority of principals described good science instruction as including "hands-on" activities. Despite this agreement, principals expressed varied definitions for "hands-on." Some principals associated hands-on with conducting experiments while for others the term was used a vague descriptor for any activity that got students "'moving and active'" (p. 446).

When noticing and evaluating classroom science instruction, principals noticed general pedagogical aspects and student engagement but not elements of instruction associated with the science practices or disciplinary-core ideas outlined in the NGSS. For example, in Video 1, which was a clip of instruction aligned with NGSS practices and disciplinary core ideas, students were sitting in a circle engaged in argumentation. Nonetheless, a participating principal, Principal 24, attended only to how many voices could be heard rather than the content of the students' discussions. The principal saw the activity as unstructured and therefore, evaluated the teacher's instruction as ineffective. Cuban (2013) describes the relationship between contextual factors and enacted instruction as "entangled and crucial" (p. 117), and McNeill et al.'s (2018) study epitomizes that description. If principals like Principal 24 do not have the expertise and experience to evaluate reform-based practices, it is possible teachers will not risk their evaluations by deviating from traditional instructional practices.

Summary

Taken together, these studies underscore the interdependent relationship of instruction and instructional context. As the above studies indicate, despite instructional supports such as professional development and educative curriculum materials, the contexts in which teachers work can hinder or distort the enactment of reform-based instruction. Enacted instruction reflects teachers' understandings and beliefs, which can limit the success of reform efforts. For Mrs. O (Cohen, 1990), that meant using new materials in old ways. For the teachers in Roychoudhury and Rice's (2010) study, that meant the teachers dismissed reform-based practices they did not understand as important to doing science. For the teachers in Concannon-Gibney and McCarthy's (2012) study, it was not their ideas that derailed reform-based instruction; teachers' efforts were challenged by students who had their own ideas about what it means to do and participate in science. Finally, teachers encounter struggles with implementing reform-based instruction when the instructional context does not provide adequate time (Bismack et al., 2014; Concannon-Gibney & McCarthy, 2012), resources (Brezicha et al., 2015), or leadership (McNeill et al., 2018).

Need for Research Prior to Reform Adoption and Implementation

As evident, there exists a wealth of research that examines the extent to which instructional practice aligns with reform-based practices and expectations (e.g., Bismack et al., 2014; Brezicha et al., 2015; Charalambous et al., 2012; Cohen, 1990; Concannon-Gibney & McCarthy, 2012; Glen & Dotger, 2013; Remillard & Bryans, 2004; Roychoudhury & Rice, 2010; Vo et al., 2015). This line of research studies instruction after reforms have been adopted and explains instructional (in)congruencies by analyzing the contextual factors that support (e.g., features of educative curriculum materials that aid teacher understanding) and constrain (e.g., students' understandings for participation) successful reform-based instruction. While this research is valuable, it assumes a reactive response to reform policies. Little research assumes a proactive approach, examining the feasibility of successful reform implementation by considering the extent to which a teacher's existing instructional context is conducive to supporting the enactment of reform-based instructional practices prior to the adoption of the reforms. A level of compatibility based on contextual resources and constraints will help teachers and school leaders determine appropriate measures for rolling-out new reforms in their schools.

Summary

The *Next Generation Science Standards* (NGSS Lead States, 2013), based on *A Framework for K-12 Science Education: Practices, Crosscutting skills, and Core Ideas* (National Research Council, 2012) and adopted in Michigan as the Michigan Science Standards (MDE, 2015) denote a paradigm shift in science education. The traditional conception of science as a body of knowledge aligned with instructional practices centered on comprehending and recalling scientific facts. The new standards call for science instruction that fosters students' disciplinary science literacy by conceptualizing science as both a set of practices and an established body of knowledge.

In the past, reforms of this magnitude have effected only modest changes in classroom instruction (Cohen, 2011; Cuban, 2013; Judson et al., 2016). Research indicates that the "sluggish" (Judson, et al., 2016, p. 2) change is at least partially attributable to reform ideals that are incongruent with elements of the instructional context. Therefore, helping teachers to enact reform-based instruction requires a thorough understanding of how the resources and constraints of the current context shape current practices and the extent to which those practices align with the goals of the new reforms. This study addresses this need by exploring the liminal space between a rural elementary teacher's existing practices in the teaching of fifth grade science and the school's adoption of the MSS (MDE, 2015).

CHAPTER III

Research Methods and Design

This dissertation is a qualitative, microethnographic, common case study of one rural elementary teacher's practices in the teaching of science. In the tradition of microethnography, this study foregrounds daily classroom interactions (Bloome et al., 2005, "Introduction," para. 3) with the understanding that complex interactions influence and are co-constructed by contextual dynamics. As a case study, it investigates a real-world phenomenon, science instruction, in its natural context, the rural classroom, where the boundaries between the context and the phenomenon are not distinct (Yin, 2014). This single-case study is a *common* case because it "capture[s] the circumstances and conditions of an everyday situation" (p. 52), science instruction in a rural teacher's fifth grade classroom.

The goals of this research were to explore the pedagogical resources and constraints that shape the instructional practices employed by a rural elementary teacher in the teaching of science and the extent to which those practices conform with a disciplinary approach to science as called for in the Michigan Science Standards (MSS; Michigan Department of Education [MDE], 2015). To meet these goals, I interviewed a fifth grade teacher from a rural elementary school and observed in her classroom over two semesters, collecting extensive data on instructional units on the solar system and the scientific method. I analyzed the data using qualitative methods, including inductive coding, content analysis, and discourse analysis. In this chapter, I present the details of the study's context and participants, data collection and analysis, and limitations.

Research Context and Participants

Context

Lake School is located in a rural town, Nibiing, in the Midwest. Like other regional public districts (excluding those on tribal reservations), students in the Nibiing district are majority white only (94%) and speak only English (~98%) (nces.ed.gov). However, at nearly 2,300 students, the Nibiing school district is one of the largest in the region. Lake School, the only upper elementary school in the district, houses approximately 500 students in Grades 4, 5, and 6. Lake School is one of the most resourced schools in the area. For this reason, I consider the site to be optimal for this study because one of the most resourced area schools still powerfully illuminates the challenges of reforms.

Lake School does not currently have a science curriculum. The teachers use a set of compact discs with printable worksheets that was purchased from a textbook company as their guide for what to teach. As of the writing of this chapter, the school has not yet adopted the state's new science standards, the Michigan Science Standards (MDE, 2015), which are based on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012) and adopted in 2015 because the principal did not have resources to support teachers in enacting instruction aligned with the MSS. The school does not have a curriculum director or science consultant at any level–school, district, nor intermediate school district–so when the school does adopt the standards, teachers will enact instruction that coheres with their available resources.

Participant

I wanted to study a teacher who had expertise in both science and literacy. Thus, I purposely sought participants who are teacher consultants (TCs) for the National Writing Project (NWP), a professional development organization that focuses on the effective teaching of writing and learning. Since TCs incorporate reading and writing throughout the day, I knew such a teacher would represent the best case for studying disciplinary literacy. I asked in a regional NWP forum for volunteers; Mrs. Stella Poppy, a pseudonym, volunteered. Mrs. Poppy received consent from her building principal with the caveat that I would not video record during observations or take photographs of students. I agreed to the terms and was granted permission to record audio, take other photographs, and write notes. With this agreement, I began visiting Mrs. Poppy's classroom in May of 2017. Neither Mrs. Poppy nor the school received any monetary compensation for participation. However, I did buy fancy sugar cookies decorated to look like a galaxy for all of the students in her classes before the end of the observations as a thank you for welcoming me into their classroom.

Mrs. Poppy is a nine-year veteran teacher and had been teaching fifth grade and fifth grade science for four years. She holds a Bachelor's degree in elementary education with two content area certifications, social studies (K-8) and science (6-8) and a Master's degree as a reading specialist. Mrs. Poppy has been ambitious in seeking out her own professional development outside of her school community. In addition to the NWP, she applied for and received a grant-funded summer professional development trip abroad for science teachers. Mrs. Poppy, therefore, is an ideal case for this study, as her professional focus since earning her teaching certificate has been on developing herself as a teacher of both literacy and science.

Mrs. Poppy and her grade level colleagues all arrange for their students' instruction in different ways. Some pair up in teams of two, switching students for some subject areas while others teach their own students all subjects. Mrs. Poppy and one of her grade level colleagues share students for science and social studies; she teaches both classes science, and he teaches both classes social studies. Each science class was roughly 40 minutes in duration. In total, during the 2016-2017 school year, Mrs. Poppy taught 51 students science four days per week. The other day of the week, the two classes' itinerants (music, art, etc.) did not align; thus, students had neither science nor social studies on that day. In the next chapter, I discuss how Mrs. Poppy navigates her professional responsibilities and personal knowledge in planning for her science lessons.

Data Sources and Collection

Semi-Structured Interview

A tenet of microethnography is the idea that people are situated. People create and recreate their contexts, yet they are cognizant of the broader contexts that influence what they do. Bloome et al. (2005) explains,

> [People] are not unaware that there are broader contexts and dynamics that influence and are influenced by what they do in their daily lives. They talk about these broader contexts and dynamics, care about them, struggle and argue with others about them, and use them in part to give meaning and value to what they do…People can and do take actions based on their understanding of broader contexts and dynamics. (Chapter 1, "Implied Personhood," para. 6).

In the context of the classroom, this means teachers enact instruction that influences and is influenced by multiple intersecting contexts.

To explore how Mrs. Poppy understands and works within these contexts Mrs. Poppy met me at a local coffee shop on a Saturday prior to the start of observations for an interview. I explained to her that as a former rural elementary teacher I was aware that new reform efforts, such as the new science standards, put a lot of pressure on rural teachers; therefore, I was interested in learning what teachers will need to meet new demands while at the same time highlighting areas in which teachers are doing very well. Mrs. Poppy agreed to help me with this research, and with her consent, the interview was audio recorded while I took notes. Over the course of the 1 hour and 40 minutes we spent together, I asked Mrs. Poppy about many facets of her science instruction, including her development as a teacher of science, her thoughts about reading and writing in science, and the way she plans for a science unit (The complete interview protocol as well as the questions added during the process is located in Appendix B). Mrs. Poppy had brought along worksheets and other materials as reminders of her planning process.

The interview forecasted much of what I would see during observations. Mrs. Poppy was very straightforward and open; for example, with few exceptions, her descriptions of the solar system unit were as I observed it. The interview provided another means of understanding the context of the observations and analyses that were to come and the challenges of science instruction for this rural teacher.

Classroom Observations

Mrs. Poppy's classroom is a vibrant room decorated with images of wildlife and full of natural light. A sandwich board at the door greets students hello and lists the items they will need for the day. I visited Mrs. Poppy's classroom for a unit on the solar system from May 8, 2017, until June 5, 2017, and for the majority of a unit on the scientific method from September 11, 2017, to September 18, 2017. During observations, I sat in the back of the room either at a table or a student desk. On two occasions, the lessons were outside of the classroom. On those days, I served as an additional chaperone as well as a researcher.

The original intent of my research, as per my proposal, was to explore how teachers in rural schools currently use texts during science instruction, how those uses (mis)align with authentic uses for texts as outlined by Cervetti and Barber (2009), and how knowledge of those uses can inform professional development designed to meet the demands of disciplinary literacy. With this intent in mind, I created an observation template for recording field notes. Accordingly, the focus for observations was texts. Thus, I ordered each text in sequence during a lesson, its title, and the class participation structure in which it was used. I also took very detailed notes about what happened following the introduction of each text, including direct quotes from the discussion surrounding the text and descriptions of Mrs. Poppy's actions in relation to the texts (i.e., draws circle on screen, spins globe, highlights on worksheet). I frequently cited in field notes the time on the audio recorder. During transcriptions, I was then able to cross-reference the time stamps on the audio recordings with those recorded in field notes. Mrs. Poppy provided me with copies of classroom handouts, so in addition to writing field notes, I completed text tasks along with the students. For example, Mrs. Poppy always projected the lessons' worksheets, and students followed along as she wrote notes, highlighted, and completed assessment questions. I, too, followed along, making the same drawings, highlighting, and annotating as directed. I took digital photographs of non-static texts, such as texts on the projector screen, texts for which I did not have a copy, and the other available classroom texts. I noted the picture numbers on the camera and wrote those numbers in the field notes as I took them. In total, I have 20 days of field notes; 12 hours, 24 minutes, and 21 seconds of audio recordings; and 161 digital photographs from two units of study, the scientific method and the solar system.

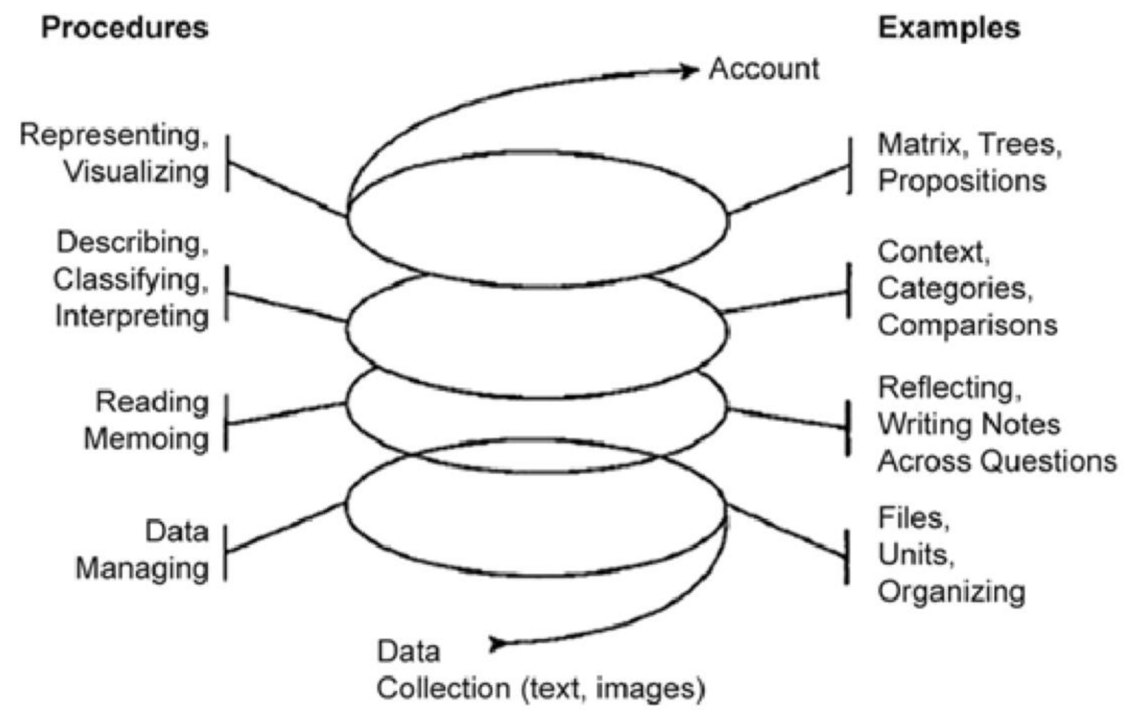
Data Coding and Analysis

Data coding and analysis began the moment the study started with a plan for organizing field notes, audio recorders, and photographs. Once collected, data from the interview and classroom observations were transcribed into workable units of analysis. Interview data were analyzed using tools from discourse analysis, and classroom observation data were analyzed through a recursive process of organizing, memoing, coding, and content analysis.

Observations

Creswell (2013) argues that data analysis is not a process achieved through the progression of linear steps. It is a process of phases that are "interrelated and often go on simultaneously" (p. 182) and is best illustrated as a spiral (see Figure 3.1). The spiral starts with data collection and ends with an account of findings. In between, the researcher engages in many iterative analytic exercises.

Figure 3.1
The Data Analysis Spiral (Creswell, 2013, p. 183)



The first loop in the data analysis spiral is data management and organization (Creswell, 2013). Once data are transcribed, organized, and stored securely, analysis continues with a recursive process of reading and memoing, the second loop. Reading through the entire data collection several times allows a researcher to get a sense of the data, which allows the researcher to organize them into more meaningful, workable chunks. Memos, according to Creswell (2013), "are short phrases, ideas, or key concepts that occur to the reader" (p. 183) and are written in the "margins of field notes or transcripts or under photographs" (p. 183). Margin notes and highlights prompt larger thoughts, which are elaborated in longer and more detailed analytic memos. These memos fall at the intersection of the reading and memoing loop and the describing, classifying, and interpreting loop, as the memos delve into deeper, contextualized description.

Analytic memos converge with the third loop, for in this loop, researchers "describe what they see" (Creswell, 2013 p. 184) and "provide interpretation in light of their own views or views of perspectives in literature…within the context of the setting of the person, place, or event" (p. 184). Analytic memos allow for the exploration of data episodes with respect to the research questions and to elaborate on the perceived significance of the episodes. The memos prompt a new lens with which to return to the data in search of similar or disconfirming episodes. Thus begins the process of "lean coding" (p. 184), identifying nascent codes from common episodes. Iteration of these three loops of the data analysis spiral result in the expansion and addition of codes and ultimately to themes, conglomerates of several codes that denote one idea.

The final phase of the spiral is representing and visualizing the data. Researchers share findings in a variety of modes, and often in more than one mode. Examples include diagrams, flow charts, tables, and texts.

I cannot imagine a better representation of my analysis process than the spiral, for I journeyed through the loops repeatedly, and at times, with great frustration, in my process of understanding. My analyses evolved as I explored different aspects about what I could learn from Mrs. Poppy and about what science is. In the following, I describe my analytic journey through the loops of the data analysis spiral as I made sense of and interpreted data collected from observations in Mrs. Poppy's classroom.

Organizing the Data

This process actually began during observations when I dated and numbered all field notes, artifacts, and photographs and set the audio recorder to store recordings by date. After observations, I transcribed audio recordings using InqScribe® and oTranscribe, and as I transcribed, I consulted the field notes for details about the actions and photographs that accompanied the audio. Actions and photograph numbers were included in brackets with the audio transcriptions. Transcribed dialogue was divided into episodes based on a change in speaker or a new-episode tag (Swales & Malczewski, 2001). A new-episode tag is a linguistic resource used to shift participation, such as from whole group to small group discussion, or to change the direction of a discussion. Examples of frequently used new-episode tags are "So," "All right," "So then," and "Okay." To make coding easier, I created two-column charts; the left column contained empty cells for handwritten codes, and the right column contained the transcriptions, split into rows by episode. This organizational structure was optimal for coding according to my original inquiry, as described in the next section.

Looping

My first journey through the spiral attempted to end with an account of the uses for texts during science instruction in light of the authentic uses of texts as outlined by Cervetti and Barber (2009). Cervetti and Barber identified five functions a text can serve during a science investigation as well as several illustrations of each function. I numbered each use described by Cervetti and Barber (2009) as a way to streamline data coding (see Figure 3.2).

Figure 3.2
Excerpt from Data Analysis Log based on Cervetti & Barber (2009)

Data Analysis Log Based on Cervetti and Barber (2009)

Function	Illustration	Recorder Time(s)	Text Examples
Provide context for inquiry-based investigations	1. Inviting students to think about their everyday experiences in a new way		
	2. Sharing an aspect of the natural word that is unfamiliar to students		
	3. Introducing the natural contexts in which scientific phenomena operate		
	4. Connecting students' everyday experiences to classroom investigations		
	5. Connecting students' investigations to a specific domain		
	6. Connecting students' investigations to the work of professional scientists		

After reading through the transcripts several times, I realized there were not any science investigations that could be understood as akin to the investigations that Cervetti and Barber (2009) use as the basis for analysis using their framework; thus, there were not any authentic uses of texts. This was an early indication that my originally intended framework might not be adequate for finding meaning in my data. However, given I also wanted to determine how knowledge of text use could inform professional development in the area of disciplinary literacy, I decided to code text use despite the lack of investigations in order to consider how those uses might be built upon for professional learning. For example, during an episode on phases of the moon and eclipses, Mrs. Poppy drew a picture and asked students to identify the type of eclipse it represented (see Figure 3.3). This was coded as #14, "providing data for the reader to interpret" (Cervetti & Barber, 2009).

Figure 3.3
Excerpt from Observation Log #8

Observation 8 - "Phases, Eclipses, and Tides" worksheets
Mrs. Poppy

	00:00
14	T: We learned about a couple things yesterday. We're going to review those and then we're going to move on. So, I'd like to ask you if you can please tell me, not out loud, please, what this is? [pictures 65 & 66]. Student?
	S: solar eclipse
	T: Solar eclipse. Very good.
	01:02
14	T: Can you tell me which moon phase that is? Specifically. [pic 67] Student 2?
	S: waning
	T: waning?
	S: waxing
	T: waxing

However, I felt these codes extended the scope of Cervetti and Barber's (2009) work to distortion. Mrs. Poppy's intent in the review was to assess students' retention of previously covered content. Assessment is not akin to providing data, such as a table of observational data, for students to interpret by describing patterns. It became apparent that I was trying to impose the work of Cervetti and Barber (2009) on the data. I needed a new angle.

Thus, in the next analysis cycle, I tried two approaches. First, I read through the transcripts again and marked episodes I found interesting. I wrote detailed memos about those episodes, describing my own interpretations of the events and connecting my thoughts and observations to literature. I used these memos as starting points for lean inductive coding (Creswell, 2013; Yin, 2014). Then, rather than identify the uses for texts, I considered the types of texts being used during the solar system unit and how students engaged with them (see Figure 3.4).

Figure 3.4

Screenshot of Table of the Solar System Unit Texts

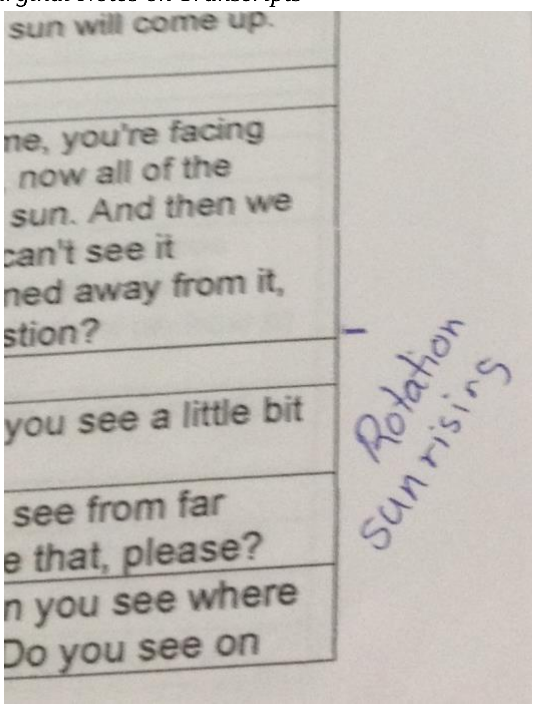
Mode	Title	Source	Task	Participation Structure
Video	Mind blowing! Earth compared to the rest of the universe	BuzzFeedBlue via YouTube	view and read	whole group
	Earth's tilt 2: Land of the midnight sun	Kahn Academy	view	whole group
	Earth's tilt 1: Reason for seasons	Kahn Academy	view	whole group
	What is the cause of high and low tides in ocean?	BBC video via YouTube	view	whole group
Book	*The book of planets* by Clint Twist			
Printable	"Earth in Space" (5 pages)	Prentice Hall	read and respond	whole group & independently
	"Gravity & Motion" (5 pages)	Prentice Hall	read and respond	whole group & independently
	"Phases, Eclipses, & Tides" (7 pages)	Prentice Hall	read and respond	whole group & independently
	graphic of moon phases (1 page)	Moonconnection.com	reference	
	"Name the Moon Phases" (1 page)	Super Teacher Worksheets	respond	
	"The Sun" (6 pages)	Prentice Hall	read and respond	whole group & independently
	"The Sun" (1 page)	Education.com	reference	whole group
	"The Inner Planets" (7 pages)	Prentice Hall	read and respond	whole group & independently
	"The Outer Planets" (8 pages)	Prentice Hall	read and respond	whole group & independently
	"Comets, Asteroids, & Meteors" (6 pages)	Prentice Hall	read and respond	whole group & independently
	"My Planet Report" (7 pages)	Super Teacher Worksheets	complete	independently
	Planet Walk Comprehesion (1 page)	Teacher prepared	respond	partner
	"Solar System Scavenger Hunt" (2 pages, 18 index cards)	Super Teacher Worksheets	complete	partner
	Solar System Pre- and Post-Test (3 pages)	Teacher prepared		independently
Brochure	"The Planet Walk"	Delta Astronomical Society	read	whole group
Poster	"Hubble Space Telescope Deep Field"	NASA	reference	whole group

The chart revealed some helpful data. One, Mrs. Poppy's resourcefulness is evident; she used materials from a variety of sources to supplement the worksheets from Prentice Hall. Secondly, there was a limited variety of text modes and tasks. Thirdly, classroom participation was largely whole group instruction followed by independent work time. These observations led to a more nuanced inspection of the task of responding. Perhaps I could learn something from the kinds of questions to which students responded.

Ergo, next I made a table that listed all the different types of tasks found on the classroom worksheets in one column and an example of each in the second (see Appendix C). There were twelve kinds of tasks: asking students to add to a diagram, answer questions regarding a diagram, label a diagram, match vocabulary words with definitions, define vocabulary words, fill in the blank with a word from a word bank, fill in the blank (no word bank), circle the correct response, circle the correct responses, answer true or false, complete a table, and write a short answer. As was the case with Mrs. Poppy's drawings of the eclipse and moon phases, these questions were intended to assess students' retention of previously covered content. Therefore, I decided to take a deeper look at content. To do that, I considered similar information at a different grain size.

In the next loop, I reread the transcripts, and I divided lessons by sequence (e.g., reviewing, reading, assessment, etc.) and wrote the content foci for each part of the sequence in the margins (see Figure 3.5).

Figure 3.5
Marginal Notes on Transcripts



I identified the text, modality, and student tasks for each content focus (see Figure 3.6) in order to identify patterns in patterns in instruction or interactions with texts.

Figure 3.6
Excerpt from Lesson Sequences Table

Observation	Overall Goal	Lesson Sequence	Foci	Text	Modality	Student Task
2: Lesson 1 of Solar System unit Lesson 1 of 4 "Earth in Space"	Earth's movement in space: rotation	Review		vocabulary words	verbal	respond to teacher questions (I-R-E)
		Reading and highlighting		concept of rotation	printed text	listen & highlight: • "rotation and revolution" • "Rotation is spinning."
		Teacher demonstration with globe, basketball, and lamp	time zones	countries	model: globe	I-R-E
			rotation and sunrising	basketball valve hole	model: basketball	determine when they could and could not see the valve hole as the basketball was rotated
			Earth's tilt	basketball valve hole and lines	model: basketball & lamp	determine when the lamp ("sun") was visible as the basketball was rotated at its tilt
			Lake City's location on the globe	mathematical computation of latitude	teacher diagram 	copy into personal science notebooks

In Figure 3.6, I noticed an overt pattern of teacher questioning. Mrs. Poppy asked students considerable questions during each lesson sequence, and the majority of questions were presented in an initiate-response-evaluate (IRE) format (Nystrand & Gamoran, 1991). I coded all the IRE cycles in the transcripts and explored some literature on IRE questioning and the role of questioning in science learning (Cervetti, DiPardo, & Staley, 2014; Krajcik & Sutherland, 2010; Nystrand & Gamoran, 1991; Ruiz-Primo & Furtak, 2007; Vo, Forbes, Zangori, & Schwarz, 2015). I found Mrs. Poppy's instruction to be akin to Rob's instruction in Ruiz-Primo and Furtak's (2007) study of three teachers. Like Rob, Mrs. Poppy continually checked students' understandings of content using IRE cycles of questioning, and her speaking turns were long in comparison to students'. At the time, I had not identified any occasions when students discussed among themselves; students were not engaged in sense-making activities. Instruction focused on understanding content presented in texts – comprehension.

Positioning Mrs. Poppy's instruction as science comprehension instruction necessitated a review of both my research questions and existing literature. My ultimate goal was still the same: What do I see that can be leveraged in professional development aimed at meeting the new demands for disciplinary literacy in science? However, my focus had changed. Rather than examine text use, I focused on practices. Specifically, I focused on her literacy practices used in the comprehension instruction I observed, and in order to identify what practices could be built upon for achieving a disciplinary literacy approach to science, I needed to also explore the science demands of the Michigan Science Standards (MDE, 2015). Thus, I sought literature for exemplars of both comprehension practices, particularly within content-areas, and science practices. These two lenses required several types of work.

First, I returned to the data and started another round of lean inductive coding (Creswell, 2013; Yin, 2014), or open coding (Merriam, 2009). My codes reflected the literature dive I had conducted into comprehension instruction. For example, I coded episodes focused on defining vocabulary words and those in which Mrs. Poppy conducted a demonstration of the content. Following this coding, I sought to understand the relationship among these codes and the story they describe. This led to a series of codes that I was able to gather into four themes: comprehension aids, attention to foundational literacy skills, missed opportunities, and critiques. These themes characterize Mrs. Poppy's instructional practices.

Second, according to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (National Research Council, 2012), the new vision for science education suggests all students should have opportunities to frame scientific questions, conduct investigations, seek scientific arguments and data, evaluate and apply arguments, and communicate their understandings and arguments to others (National Research Council, 2012, p.

278), all of which are higher-order processes. To determine how these expectations compare to the tasks being asked of students in Mrs. Poppy's class, I coded the worksheet tasks (Appendix D), and the previous standards, the Michigan Grade Level Content Expectations (GLCEs; MDE, 2007), according to the revised version of Bloom's Taxonomy (Krathwohl, 2002). The revised version contains two dimensions, the Knowledge dimension and the Cognitive dimension. The Knowledge dimension identifies four types of knowledge that transcend subject areas: factual, conceptual, procedural, and metacognitive. The Knowledge dimension of an objective (or standard or task) is determined by considering the noun phrase. The Cognitive domain is a hierarchy of six categories of cognitive processes that increase in complexity from the lowest level to the sixth level: remember, understand, apply, analyze, evaluate, and create. These six categories are further explained by 19 total subcategories. The Cognitive process is identified by the objective's verb. For example, for the objective "Name the 50 states," the noun phrase (the 50 states) indicates factual knowledge and the verb (name) requires the cognitive process of remembering.

In this process, I considered the GLCEs holistically. The GLCEs are organized by grade level and then by discipline, of which there are four, science processes, physical science, life science, and Earth science. For each discipline, there is at least one broad K-7 standard. These broad standards are then explained and narrowed by grade level into content statements and specific content expectations, referred to as GLCEs. In determining the Knowledge and Cognitive dimensions of the GLCEs, I considered the overall standard as well. For example, the following table contains a broad K-7 standard (S.IP), a content statement (S.IP.M.1), and a GLCE (S.IP.05.15) for the discipline of Science Processes.

Figure 3.7
Excerpt from Knowledge and Cognitive Dimensions of GLCEs (MDE, 2007)

Content Statement by Standard: Science Processes	Specific Content Expectation	Knowledge and Cognitive Dimension
S.IP Develop an understanding that scientific inquiry and reasoning involves observing, questioning, investigating, recording, and developing solutions to problems.		C. Procedural 2.0 Understand
S.IP.M.1 Inquiry involves generating questions, conducting investigations, and developing solutions to problems through reasoning and observation.	S.IP.05.12 Design and conduct scientific investigations.	C. Procedural Knowledge 3.1 Apply: Executing

The GLCE (S.IP.05.15) for this science process is coded along the Knowledge dimension as Procedural knowledge and along the Cognitive dimension as the third level of the taxonomy, Apply, or "carrying out or using a procedure in a given situation" (Krathwohl, 2002, p. 215). This GLCE is coded this way for two reasons. One, the broad standard for this GLCE tells us that as whole, the GLCEs within this standard are about Understanding (2.0) Procedural knowledge (C). The second reason is, as mentioned, within the Grade Level Content Expectations, Science Processes is its own discipline, independent from the other disciplines. Thus, the primary objective of the Science Processes expectations is to understand the processes- rather than use the skills for the generation of scientific knowledge in life, Earth, and physical sciences. Therefore, the GLCE (S.IP.05.12) suggests that students should use the scientific procedure of designing and conducting scientific investigations as a way of understanding that inquiry involves investigations.

By identifying the knowledge and cognitive processes demanded by the current standards and classroom tasks, I could discern the overall goals for current science instruction. The next step was to repeat the process for the new science standards, the Michigan Science Standards

(MSS; MDE, 2015). I identified the Knowledge and Cognitive dimensions of the performance expectations for the three standards for fifth grade Space Systems: Stars and the Solar System.

For additional comparison, I used conceptual content analysis (Busch et al., 1994-2012) to compare the GLCEs for fifth grade Earth science and the fifth grade performance expectations for Space Systems: Stars and the Solar System. To do this, I created a word cloud for each set of standards using the online application TagCrowd (https://tagcrowd.com/). I entered the expectations verbatim, and for both clouds, I excluded prepositions (i.e., around, between, from, in, of, on, to, with, within), articles (i.e., a, an, the), demonstrative pronouns (i.e., these, those), linking verbs (i.e., is, are), and conjunctions (i.e., and, that). I also set a minimum frequency of two occurrences. These word clouds provided a visual for word frequencies, providing another way to determine what each set of expectations values and deems important.

From all these analyses, I saw that my research questions could be revised to bring out the key findings my research was uncovering. The instruction I observed was not reflective of disciplinary literacy, but it was not uninformed and was grounded in some understanding of both science and literacy. Therefore, I sought to understand what informed the instruction and what conceptualizations were possible given those resources.

Interview

My second major data source was my interview with Mrs. Poppy. Interviews are a common means of qualitative data collection. They allow for the collection of data that cannot be observed, such as feelings, thoughts, opinions, and personal interpretations of experiences (Merriam, 2009), and thus, necessitate analysis of the discourse in which such are shared. To analyze the interview transcripts, I used tools from systemic functional linguistics and discourse analysis.

According to systemic functional linguistics, language realizes its social contexts through three metafunctions: interpersonal, ideational, and textual. Interpersonal reveals relationships, ideational construes an experience, and textual organizes discourse (Rose, 2012). For this study, I focused my data analyses on ideational and interpersonal metafunctions.

Ideation is the content that builds a theory of experience. I wanted to understand Mrs. Poppy's experiences with teaching science, disciplinary literacy, and planning lessons, so I coded Mrs. Poppy's responses to my interview questions for ideational similarity. I coded reoccurring references that construed her experience for a particular circumstance. For example, I identified all responses in which she spoke of a resource or construct that influences her instruction.

Then, I examined the interpersonal meaning in the data. Recall that interpersonal meaning reveals relationships; it also conveys attitudes. To identify Mrs. Poppy's attitudes, I used the discourse analysis tool of Appraisal, which "explores how interpersonal meaning permeates a text enabling exploration of resources for evaluative meaning" (Schleppegrell, 2012, p. 26). I examined the data for tokens of appraisal: AFFECT, JUDGMENT, and APPRECIATION (Martin & Rose, 2003). In the appraisal system, AFFECT is "the resource deployed for construing emotional responses" (Martin, 2000, p. 145). Tokens of AFFECT might be present in an expression of feelings regarding experiences or processes. For example, in the study, Mrs. Poppy expressed POSITIVE AFFECT: HAPPINESS when she shared her pleasure in teaching complex vocabulary words, "I love it*"* (Poppy, personal communication, May 8, 2017)! Tokens of JUDGMENT evaluate human behavior or morals (Martin, 2000, p. 145), such as an evaluation of students, the school, or oneself. For instance, in appraising her ability to engage students with science, Mrs. Poppy judged her capacity to motivate positively (POSITIVE JUDGMENT: CAPACITY), "It works so great. Like, if I'm excited about stuff, they're excited about stuff." Finally, tokens of APPRECIATION construe "the 'aesthetic quality of semiotic text/processes and natural phenomenon" (Martin, 2000, pp. 145-146); in other words, APPRECIATION expresses how an actor feels about things (Martin & Rose, 2003), such as an expression of opinions about materials or resources. For instance, "It was really creative!" (POSITIVE APPRECIATION: REACTION: QUALITY) expressed Mrs. Poppy's appreciation for the quality of a student's final project for the fifth grade unit on animal adaptation.

According to Mills, Birks, & Hoare (2014), "Explanations of data are presented in context and participants' voices are portrayed as integral to the analysis and presentation of findings" (p. 111). Indeed, Mrs. Poppy's responses to interview questions were integral. I used my ideational coding to be able to report about the resources upon which Mrs. Poppy drew for her instruction, and I infused the interpersonal analysis into my findings to show her stance toward the activities she described.

Summary of Data Analysis

The data analysis spiral accurately represents the iterative process through which I analyzed data collected through classroom observations and a semi-structured interview. Every table, round of coding, and memo highlighted something new in the data and prompted new questions that I could ask. Analyses evolved as I explored different aspects about what I could learn from Mrs. Poppy. For example, my original inquiry created a deficit understanding (this is not disciplinary literacy), but further analyses changed that perspective to an understanding of Mrs. Poppy's teaching as informed instruction based on available resources and in compliance with responsibilities. The different lenses and theoretical frameworks enable me in the next chapters to explore the roles of curriculum, classroom interactions, understanding of science, teacher practices, and the rationality of Mrs. Poppy's choices given the context.

Study Risks and Limitations

Managing Risks to Participants

The purpose for this study depended upon the authenticity of classroom instruction and events, and thus, this study (HUM00101397) is exempt from IRB review according to Exception #1 of the 45 CFR 46.101.(b), which exempts studies of "normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques…"

I received consent from the participant and her building principal to conduct the study in the participant's fifth grade classroom. The only participant in this study was the teacher. Therefore, I did not interview or photograph students, and I was certain not to photograph any texts, such as worksheets, that had student writing already on them.

In order to protect the identity of the participant, she was asked to choose a pseudonym for herself (Stella Poppy) and her school. However, in any classroom study, the teacher is vulnerable, and the vulnerability is not limited to accurate identification.

Mrs. Poppy and I knew each other as members of the same cohort of NWP TCs, but we did not have a personal relationship prior to the start of the study. However, as happened with McCarthey (2001) and her research participant, Mrs. Poppy and I developed a personal and social friendship as a result of the time we spent together in her classroom. I consider Mrs. Poppy my friend and colleague. This relationship poses a conundrum of sorts. For as Newkirk (1996) contends, "Anyone who spends a great deal of time in a teacher's classroom, particularly someone who has experience in a similar teaching situation, will observe practices that seem ineffective. And some of these will probably relate to the issues the researcher is examining" (p. 13). This is problematic for those with personal relationships because according to Jack Douglas (as cited in Newkirk, 1996), with friendship, there is an implicit obligation not to report things that might cause our friends distress. I took precautions for managing this risk by informing Mrs. Poppy prior to the interview that the intent of the study was to identify what rural teachers would need in order to meet the pressures of new science reforms and to highlight the areas in which they are doing well. In addition, I frequently talked with Mrs. Poppy about my findings and the direction of this dissertation. Further, it was important to me to establish Mrs. Poppy as representative of all the science instruction I have ever witnessed in our region – my own included. Mrs. Poppy's approach to science is not unlike the science of my coworkers' in five different school districts or that of the classroom teachers with whom I placed my pre-service teachers during my time as an adjunct faculty member.

Limitations

While Mrs. Poppy's teaching of science is representative of elementary teachers in the local rural communities, teachers work in diverse contexts and experience diverse affordances and constraints.

Furthermore, I observed one teacher for two units, one at the beginning and one at the end of the school year. A larger sample would allow for examining patterns of practice across cases. It is also possible that other units, perhaps the force and motion unit, involve different instructional practices than those I observed.

Additionally, there are limitations related to my role as a researcher. I was an observer with a background in elementary education, math, Spanish, and literacy. An observer with different expertise, particularly in science, might have noticed other aspects of Mrs. Poppy's teaching to highlight in the findings. Moreover, it is possible that as a member of this community, I observe with a slight bias and extend a bit more grace to my colleague than would an outside researcher. However, a researcher from outside the community might also propose generic strategies for implementing new science practices that are not sufficient or effective in helping teachers within this particular context to do just that.

My professional goal is to continue to live and work in the community with the aim of helping to improve our educational contexts by designing differentiated professional learning opportunities. This study allowed me to see instruction from a new perspective, but as a member of the community, I can bring recommendations for practice from an understanding and appreciation for the advantages and constraints that shape instruction in the local schools.

CHAPTER IV

Findings

The new Michigan Science Standards (MSS; Michigan Department of Education [MDE], 2015) are based on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012), which calls for students to employ knowledge of and generate scientific ideas through authentic scientific practices. These new standards are vastly different from the previous science standards, the Grade Level Content Expectations (GLCEs; MDE, 2007). Therefore, teachers tasked with implementing the MSS will need support for transforming their own understanding of science and their subsequent science instructional practices. The extent to which current instructional practices conform to the expectations of the new standards will determine the type and focus of that support. Therefore, in this chapter I report on my analysis of an interview with and observations of a rural fifth grade teacher whose school had not yet adopted the MSS. The question guiding my analyses was *How do pedagogical resources and constraints shape a teacher's instructional practices in the teaching of elementary science, and to what extent do these practices conform with a disciplinary approach to science?*

Through a combination of grounded theory, discourse analysis, and content analysis, I make the following claims:

- The participating teacher, Mrs. Poppy, is committed to implementing science instruction coherent with her accessible resources. These resources, as identified by her during the interview, include the state-mandated standards, school policies and provisions, and her own experience and knowledge. These resources also constrain her instructional practices by suggesting a conceptualization of science as a static collection of established facts.

- Mrs. Poppy's instruction is constrained by a lack of curriculum and curricular materials for teaching fifth grade science and the school's disorganized system for science education.
- The accessible resources suggest an approach to science instruction and learning that prioritizes comprehension and retention of content knowledge and is based on teacher-centered pedagogy. This instruction is best described as a content-area literacy approach.
- Attention to content is insufficient for meeting the demands of the MSS which call for student sense-making through disciplinary practices that generate, employ, evaluate, and share scientific knowledge.
- Several existing pedagogical practices can be reconceptualized to more closely approximate the instructional practices expected of the MSS.

In this chapter, I support these findings in response to the research questions. First, however, because every great endeavor starts with the goal in mind, I begin this chapter with a brief review of the Michigan Science Standards (MDE, 2015). Then, I share synopses of the two units of study I observed in Mrs. Poppy's fifth grade science classroom as an orientation to the readers about the instructional work that is the focus of this chapter.

The New Vision: The Michigan Science Standards

In accordance with *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012; hereafter referred to as the *Framework*) the new Michigan Science Standards (MDE, 2015) call for disciplinary literacy instruction, which is instruction at the intersection of the *Framework*'s three dimensions (see Appendix A). The first dimension describes science and engineering practices that lead to the generation of scientific knowledge. According to the *Framework* (National Research Council, 2012), these eight practices "cultivate students' scientific habits of mind, develop their capabilities to engage in scientific inquiry, and teach them how to reason in a scientific context" (National Research Council, 2012, p. 41). The second dimension describes the scientific concepts that transcend science disciplines, creating a coherent scientific understanding of phenomena. The third dimension, core ideas, describes the necessary conceptual understandings of each science discipline and topic. The *Framework* asserts that these three dimensions should be interwoven into resulting standards, curricula, and lessons, as they are in the MSS. In this section, I provide a brief overview of the MSS with particular attention to the standards that are most relevant for comparisons with the units I observed for this study.

As mentioned in the first chapter, the MSS for elementary are arranged by grade level and then by topics. In fifth grade, there are five topics: Structure and Properties of Matter; Matter and Energy in Organisms and Ecosystems; Earth's Systems; Space Systems: Stars and the Solar System; and Engineering Design. These topics are divided into standards, which are written as performance expectations, or authentic disciplinary tasks that employ and generate scientific knowledge. Each standard incorporates the three dimensions. For example, the fifth grade standard 5-PS2-1, which reads, "Support an argument that the gravitational force exerted by Earth on objects is directed down" (MDE, 2015, p. 19), calls for students to develop an argument from evidence and to apply the crosscutting concept of cause and effect to deepen their conceptual understanding of gravitational force (see Table 4.1)

Table 4.1
The 3 Dimensions of a Standard

Dimension	Specifics of Dimension	Component of Standard
1. Science practices	Engaging in argument from evidence	Support an argument
2. Crosscutting concepts	Cause and effect	exerted by Earth on objects
3. Disciplinary core ideas	PS2.B: Types of interactions	gravitational force is directed down

The performance expectations are further explained by Evidence Statements, or specific student tasks that indicate proficiency of the performance expectation (see Table 4.2).

Table 4.2
MSS Expectations and Evidence Statements

MSS Performance Expectation	Evidence Statement
5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects in directed down.	Students identify a given claim to be supported about a phenomenon. The claim includes the idea that the gravitational force exerted by Earth on objects is directed down toward the center of Earth.
	Students identify and describe the given evidence, data, and/or models that support the claim.
	Students evaluate the evidence to determine whether it is sufficient and relevant to support the claim.
	Students describe whether any additional evidence is needed to support the claim.
	Students use reasoning to connect the relevant and appropriate evidence to support the claim with argumentation. Students describe a chain of reasoning.
5-ESS1-1 Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.	Students identify a given claim to be supported about a phenomenon. The claim includes the idea that the apparent brightness of the sun and stars is due to their relative distances from Earth.
	Students describe the evidence, data, and/or models that support the claim.
	Students evaluate the evidence to determine whether it is relevant to supporting the claim, and sufficient to describe the relationship between apparent size and apparent brightness of the sun and other stars and their relative distances from Earth.
	Students determine whether additional evidence is needed to support the claim.
	Students use reasoning to connect the relevant and appropriate evidence to the claim with argumentation. Students describe a chain of reasoning.
5-ESS1-2 Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.	Using graphical displays (e.g., bar graphs, pictographs), students organize data pertaining to daily and seasonal changes caused by the Earth's rotation and orbit around the sun. Students organize data.
	Students use the organized data to find and describe relationships within the datasets.

The performance expectations and corresponding evidence statements focus on the language and literacy skills that are essential for doing science. They articulate a disciplinary approach to science instruction that centers on students generating, using, analyzing, evaluating and sharing scientific information, all higher-order cognitive processes (Krathwohl, 2002). The MSS also are intentionally worded to position students as agentive in their learning. Student-centered instruction that requires higher-order cognitive processing and draws on the language and literacy tasks of scientific inquiry is very different than the instruction I observed in Mrs. Poppy's classroom. In the next section, I describe each unit to situate the forthcoming analyses and provide a lens for juxtaposing instruction with the GLCEs (MDE, 2007) and the MSS (MDE, 2015).

Observed Units

I visited Mrs. Poppy's classroom for the observation of two units of study, a unit on the scientific method (TSM) and a unit on the solar system. The synopses of both units establish the context for the analysis results that follow in later sections.

The Scientific Method Unit

The Scientific Method (TSM) unit was an eight-day sequence that explored "a series of steps used by scientists to find answers to questions" (CrazyScienceLady, 2015, slide 1). The unit began with a pre-test for which the students cut out the steps of TSM and glued them onto another sheet of paper in the order students predicted was correct. This was followed by a discussion about, and note taking from, a slideshow presentation (2 days), a penny investigation (2 days), and a bouncy ball investigation (3 days).

Instruction about TSM revolved around the content from a slideshow Stella downloaded from a teacher resource marketplace, Teachers Pay Teachers. Mrs. Poppy read through and discussed the slideshow, and as she did, she directed students on filling in an outline that corresponded with each slide. The slideshow presented TSM in the following order, using a hypothetical investigation, *Does listening to music while studying help you learn?* to explain each step:

Step 1: State the Problem
Step 2: Gather Information
Step 3: Form a hypothesis
Step 4: Experiment
Step 5: Analyze Data
Step 6: Draw a Conclusion

The fourth and fifth days of the unit involved a model investigation, an investigation for the purpose of following the steps in TSM and verifying the information from the slideshow. Each student was given an investigation sheet to record information, regarding the problem "How many drops of water can fit on a penny?" Once students copied the problem statement onto their sheets, Mrs. Poppy read a paragraph about water that provided the information for forming a hypothesis about the number of drops of water that will fit on a penny. Then, students were divided into groups to experiment. Students took turns using an eyedropper and counting the number of the drops that fit on the penny before the water spilled off the side of the penny. To analyze data, Mrs. Poppy convened the whole class and recorded the greatest and fewest number of drops. Students recorded these numbers on their sheets. Then, students were instructed to write conclusions about why their hypotheses were correct or incorrect.

The remaining days of the unit were akin to the previous two with another verification investigation. This time, the students answered the question, "What effect does the drop height have on how high a bouncy ball will bounce when dropped?"

The Solar System Unit

The Earth Science unit, called the "solar system unit" by Mrs. Poppy, spanned several weeks from early May until the end of the school year in June. I observed 18 lessons. The lessons were structured around Pearson Prentice Hall worksheets that served as both the mode of learning content and the assessments. Mrs. Poppy projected a copy of the day's worksheet using a document camera and read the text as students followed along. She stopped frequently to note important text that the students should highlight, to discuss what had been read, or to draw a diagram or picture to illustrate the text. Mrs. Poppy completed all the worksheet tasks with the students by reading aloud the task and asking for students to respond orally. The final pages of each worksheet packet contained a "Section Summary" of the presented material and at least one page of "Review and Reinforce," which contained assessment items. Students completed these pages independently, writing some answers in their science journals and others on the worksheets. Students were required to respond to short answer items in complete sentences that restated the questions.

Mrs. Poppy complemented the worksheets with video clips, demonstrations of the movement of the Earth and moon in space, picture books, and other activities, including a scavenger hunt and a walk to model the proportional distances between planets. The final project was a packet of worksheets titled, "My Planet Report," which Mrs. Poppy downloaded from a teacher resource website, Super Teacher Worksheets©. Students chose a planet, save Pluto, and then used picture books and web searches to complete the packets.

In the next section, I discuss the resources Mrs. Poppy identified during the interview as influencing her instructional decisions, and I analyze the conceptualizations of science afforded by these resources using Bloom's Taxonomy (Krathwohl, 2002).

Resources that Inform and Constraints that Limit Mrs. Poppy's Science Instruction

Recall that Mrs. Poppy teaches fifth grade at the only upper elementary school in the district. The district did not have a formal fifth grade science curriculum nor had it yet adopted the MSS. Despite these missing supports, throughout the interview Mrs. Poppy mentioned specific policy, school, and personal resources that guide her instruction. In particular, Mrs. Poppy mentioned her teacher preparation courses, the standards for which she is responsible, and the materials provided by the school.

In the following sections, I analyze how the resources available to Mrs. Poppy functioned in the context of the two units I observed for this study and show how they set her up for instruction that prioritizes understanding. I begin with discussion of the GLCEs.

Determining What To Teach: The GLCEs Prioritize Understanding

During the interview, Mrs. Poppy said she determines what to teach by consulting the previous standards, "We still use the GLCEs in our school. We have not adopted [the MSS]. But, we start there, of course, because it's required. We have to go by the standards" (p. 3). When I followed up with Mrs. Poppy for the writing of this paper, I inquired as to whether her school used the GLCE (MDE, 2007) companion documents, but she said all she has are the GLCEs. The GLCEs that correspond with the scientific method and solar system unit are Science Processes and Earth Science, respectively. In this section, I discuss the conceptualizations of science afforded by these GLCEs by analyzing their knowledge and cognitive demands.

The GLCEs are organized by grade level and then by discipline, of which there are four, science processes, physical science, life science, and Earth science. For each discipline, there is at least one broad K-7 standard; there are three standards for science processes and two standards for Earth science. When parsed into sentences and coded according to the revised version of Bloom's Taxonomy (Krathwohl, 2002), the GLCEs for science processes demand only procedural knowledge while those for Earth science require only conceptual knowledge. In addition, along the Cognitive dimension, all standards statements are only at the level of

Understand (2.0) (see Table 4.3), which according to Krathwohl (2002) "is a widespread synonym for comprehending" (p. 214).

Table 4.3
Science GLCE Standards

Science Processes Standards Parsed by Statement	Knowledge Dimension	Cognitive Process
S.IP: Develop an understanding that scientific inquiry and reasoning involves observing, questioning, investigating, recording, and developing solutions to problems.	C. Procedural	2.0 Understand
S.IA: Develop an understanding that scientific inquiry and investigations require analysis and communication of findings, using appropriate technology.	C. Procedural	2.0 Understand
S.RS: Develop an understanding that claims and evidence for their scientific merit should be analyzed.	C. Procedural	2.0 Understand
S.RS: Understand how scientists decide what constitutes scientific knowledge.	C. Procedural	2.0 Understand
S.RS: Develop an understanding of the importance of reflection on scientific knowledge and its application to new situations to better understand the role of science in society and technology.	C. Procedural	2.0 Understand
Earth Systems Standards Parsed by Statement	**Knowledge Dimension**	**Cognitive Process**
E.ES: Develop an understanding of the warming of the Earth by the sun as a major source of energy for phenomenon on Earth and how the sun's warming relates to weather, climate, seasons, and the water cycle.	B. Conceptual	2.0 Understand
E.ES: Understand how human interaction and use of natural resources affect the environment.	B. Conceptual	2.0 Understand
E.ST: Develop an understanding that the sun is the central and largest body in the solar system and that Earth and other objects in the sky move in a regular and predictable motion around the sun.	B. Conceptual	2.0 Understand
E.ST: Understand that those motions explain the day, year, moon phases, eclipses and the appearance of motion of objects across the sky.	B. Conceptual	2.0 Understand
E.ST: Understand that gravity is the force that keeps the planets in orbit around the sun and governs motion in the solar system.	B. Conceptual	2.0 Understand
E.ST: Develop an understanding that fossils and layers of Earth provide evidence of the history of Earth's life forms, changes over long periods of time, and theories regarding Earth's history and continental drift.	B. Conceptual	2.0 Understand

These standards characterize the overarching goals for science education in the state. As Table 4.3 shows, the standards identify understanding of conceptual knowledge and understanding of procedural knowledge as the principal objectives.

These broad standards are then explained and narrowed by grade level into content statements and specific content expectations, referred to as GLCEs. The content statements explain exactly what about the broad standard the students should understand, and the GLCEs identify what students need to be able to do to demonstrate their understanding. The 18 content expectations for Science Processes and 8 content expectations for Earth science are coded according to the revised version of Bloom's Taxonomy in Tables 4.4 and 4.5, respectively.

Table 4.4
Knowledge and Cognitive Demands of Science Process GLCEs

Content Statement by Standard Science Processes	**Specific Content Expectation**	**Knowledge & Cognitive Dimensions**
Develop an understanding that scientific inquiry and reasoning involves observing, questioning, investigating, recording, and developing solutions to problems.		C. Procedural 2.0 Understand
S.IP.M.1 Inquiry involves generating questions, conducting investigations, and developing solutions to problems through reasoning and observation.	S.IP.05.11 Generate scientific questions based on observations, investigations, and research.	C. Procedural 3.1 Apply: Executing
	S.IP.05.12 Design and conduct scientific investigations.	C - 3.1
	S.IP.05.13 Use tools and equipment (spring scales, stop watches, meter sticks and tapes, models, hand lens) appropriate to scientific investigations.	C - 3.1
	S.IP.05.14 Use metric measurement devices in an investigation.	C - 3.1
	S.IP.05.15 Construct charts and graphs from data and observations.	C - 3.1
	S.IP.05.16 Identify patterns in data.	C - 3.1

Develop an understanding that scientific inquiry and investigations require analysis and communication of findings, using appropriate technology.		C - 2.0
S.IA.M.1 Inquiry includes analysis and presentation of findings that lead to future questions, research, and investigations.	S.IA.05.11 Analyze information from data tables and graphs to answer scientific questions.	C. Procedural 2.1 Understand: Interpreting C - 3.1
	S.IA.05.12 Evaluate data, claims, and personal knowledge through collaborative science discourse.	C - 2.1 C - 3.1
	S.IA.05.13 Communicate and defend findings of observations and investigations using evidence.	C. Procedural 2.4 Understand: Summarizing 2.7 Understand: Explaining
	S.IA.05.14 Draw conclusions from sets of data from multiple trials of a scientific investigation.	C. Procedural 2.5 Understand: Inferring
	S.IA.05.15 Use multiple sources of information to evaluate strengths and weaknesses of claims, arguments, or data.	C - 2.1 C - 2.4
Develop an understanding that claims and evidence for their scientific merit should be analyzed. Understand how scientists decide what constitutes scientific knowledge. Develop an understanding of the importance of reflection on scientific knowledge and its application to new situations to better understand the role of science in society and technology.		C - 2.0 D - 2.0
S.RS.M.1 Reflecting on knowledge is the application of scientific knowledge to new and different situations. Reflecting on knowledge requires careful analysis of evidence that guides decision-making and the application of science throughout history and within society.	S.RS.05.11 Evaluate the strengths and weaknesses of claims, arguments, and data.	C - 2.1
	S.RS.05.12 Describe limitations in personal and scientific knowledge.	D. Metacognitive 2.7 Understand: Explaining
	S.RS.05.13 Identify the need for evidence in making scientific decisions.	C - 2.7
	S.RS.05.15 Demonstrate scientific concepts through various illustrations, performances, models, exhibits, and activities.	C - 2.7

	S.RS.05.16 Design solutions to problems using technology.	C - 3.1
	S.RS.05.17 Describe the effect humans and other organisms have on the balance in the natural world.	C - 2.7
	S.RS.05.19 Describe how science and technology have advanced because of the contributions of many people throughout history and across cultures.	C - 2.7

From this table, we see that the gist of the Science Processes standards is to understand skills associated with science by executing them. Hence, the majority of the GLCEs for Science Processes are coded along the Knowledge dimension as Procedural knowledge and along the Cognitive dimension as the third level of the taxonomy, Apply, or "carrying out or using a procedure in a given situation" (Krathwohl, 2002, p. 215). It is important to note that these skills are unattached from content because as mentioned above, the GLCEs consider Science Processes a discipline independent from the other disciplines of science. Therefore, the primary objective of the science process expectations is to understand rather than use the skills for the generation of scientific knowledge in life, Earth, and physical sciences.

For the Earth Science GLCEs, we see a focus not on processes but on content and low-level cognitive demands for conceptual knowledge (see Table 4.5).

Table 4.5
Knowledge and Cognitive Demands of Earth Science GLCEs

Content Statement by Standard Earth Science	**Specific Content Expectation**	**Knowledge & Cognitive Dimensions**
Develop an understanding of the warming of the Earth by the sun as a major source of energy for phenomenon on Earth and how the sun's warming relates to weather, climate, seasons, and the water cycle. Understand how human interaction and use of natural resources affect the environment.		B. Conceptual 2.0 Understand

E.ES.M.6 Seasons- Seasons result from annual variations in the intensity of sunlight and length of day due to the tilt of the Earth on its axis, and revolution around the sun.	E.ES.05.61 Demonstrate using a model, seasons as a result of variations in the intensity of sunlight caused by the tilt of the Earth on its axis, and revolution around the sun.	B. Conceptual 2.7 Understand: Explaining
	E.ES.05.62 Explain how the revolution of the Earth around the sun defines a year.	B - 2.7
Develop an understanding that the sun is the central and largest body in the solar system and that Earth and other objects in the sky move in a regular and predictable motion around the sun. Understand that those motions explain the day, year, moon phases, eclipses and the appearance of motion of objects across the sky. Understand that gravity is the force that keeps the planets in orbit around the sun and governs motion in the solar system. Develop an understanding that fossils and layers of Earth provide evidence of the history of Earth's life forms, changes over long periods of time, and theories regarding Earth's history and continental drift.		B - 2.0
E.ST.M.1 Solar System – The sun is the central and largest body in our solar system. Earth is the third largest planet from the sun in a system that includes other planets and their moons, as well as smaller objects, such as asteroids and comets.	E.ST.05.11 Design a model that describes the position and relationship of the planets and other objects (comets and asteroids) to the sun.	B. Conceptual 2.2 Understand: Exemplifying
E.ST.M.2 Solar System Motion - Gravity is the force that keeps most objects in the solar system in regular and predictable motion.	E.ST.05.21 Describe the motion of planets and moons in terms of rotation on axis and orbits due to gravity	B - 2.7
	E.ST.05.22 Explain moon phases as they relate to the position of the moon in its orbit around the Earth, resulting in the amount of observable reflected light.	B - 2.7
	E.ST.05.23 Recognize that nighttime objects (stars and constellations) and the sun appear to move because the Earth rotates on its axis and orbits the sun.	B. Conceptual 1.1 Remember: Recognizing
	E.ST.05.24 Explain lunar and solar eclipses based on the relative positions of the Earth, moon, and sun, and the orbit of the moon.	B - 2.7

	E.ST.05.25 Explain the tides of the oceans as they relate to the gravitational pull and orbit of the moon.	B - 2.7

The above table shows that the Earth Systems standards, those that informed Mrs. Poppy's teaching of the solar system unit, focus largely on understanding, specifically explaining, conceptual knowledge.

As mentioned, Mrs. Poppy said she determines what to teach by consulting the GLCEs, and her commitment to teaching the Earth science expectations, for which she is responsible, is evident in her lessons. Mrs. Poppy's addressed each GLCE in her lessons and the unit assessment (see Appendix E for an alignment chart).

In this section, we see that Mrs. Poppy's interview responses show she is attentive to the responsibilities bestowed upon her by policy mandates, the GLCEs. In addition, we see how this resource, the GLCEs, is also a constraint as it suggests that science processes are a checklist of procedures to understand. While knowing how to do specific scientific skills is important, like reading comprehension strategies, these skills are a means to sense-making and not the goal themselves. Further, because the GLCEs consider science processes as their own discipline rather than the foundation for all domains of science, the expectations for Earth science instruction are limited in their level of cognitive challenge, requiring only that students understand conceptual knowledge. Remembering and understanding are important as the base of Bloom's Taxonomy (Krathwohl, 2002), but in order to meet the demands of the *Framework* (National Research Council, 2012) and the MSS (MDE, 2015), teachers and students will need to engage in higher-order cognitive processes, including analyzing (4.0), evaluating (5.0), generating (6.1), planning (6.2), and producing (6.3).

In the next section, I explore another influence on Mrs. Poppy's instruction, the materials provided to her by the school.

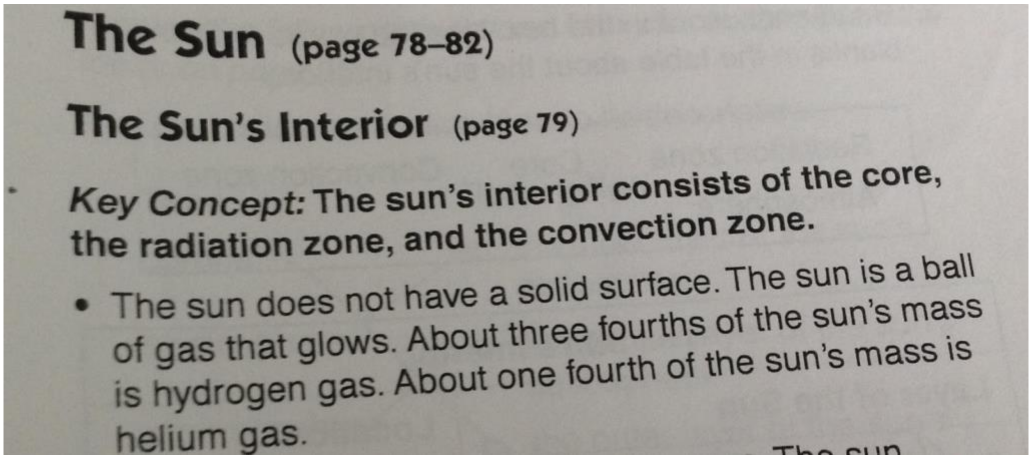
School Provisions: Worksheets Focus on Remembering and Understanding

At the interview, I asked Mrs. Poppy about the district curriculum for science. The district does not have a formal curriculum framework of goals and activities, but according to Mrs. Poppy, it does provide "a pack of CDs [from Pearson Prentice Hall] that we are able to print off from" (p. 3). The CDs are important, for as Ball and Cohen (1996) explain, instructional materials are the "stuff of lessons and units, or what teachers and students do" (p. 6). Therefore, in this section, I describe the CDs' printables (referred to as "worksheets") and analyze her implementation of the worksheets in her teaching.

For the solar system unit, Mrs. Poppy used three types of worksheets: "Adapted Reading and Study," "Section Summary," and "Review and Reinforce." The "Adapted Reading and Study" worksheets divide a textbook chapter into sections. Each section is presented as a series of bulleted lists followed by comprehension questions. These worksheets were the crux of the unit lessons. The "Section Summary" worksheets provide a review of a textbook chapter while the "Review and Reinforce" present a variety of comprehension questions to check for understanding. Mrs. Poppy assigned the "Review and Reinforce" as independent work and used the scores for documenting student learning of content.

The school did not provide other materials to support the worksheets. Mrs. Poppy did not have a teacher's manual, pacing guide, or any other ancillary items typical of a textbook program. However, the CDs' worksheets are designed to accompany a student textbook, as indicated by the parenthetical page numbers following the headings on the "Adapted Reading and Study" worksheets (see Figure 4.1).

Figure 4.1
Worksheet Excerpt with Textbook References


The Sun (page 78–82)

The Sun's Interior (page 79)

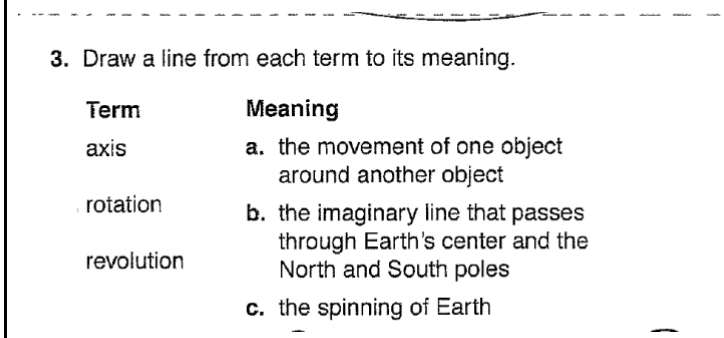
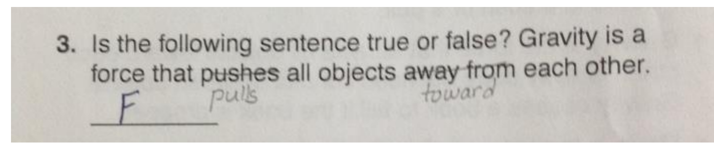
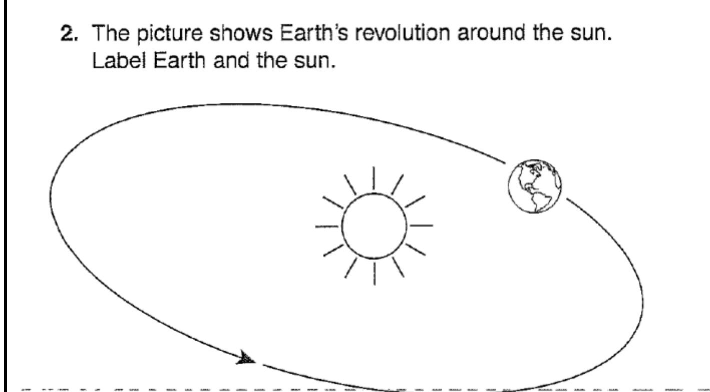
Key Concept: **The sun's interior consists of the core, the radiation zone, and the convection zone.**

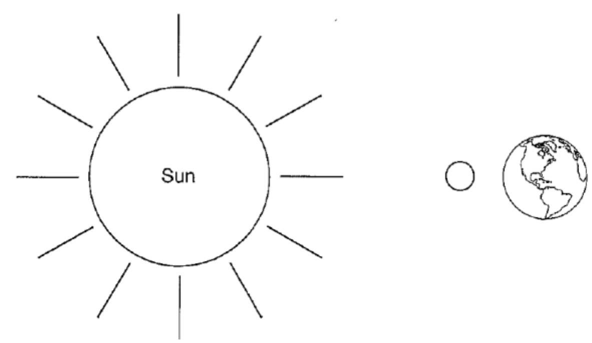
- The sun does not have a solid surface. The sun is a ball of gas that glows. About three fourths of the sun's mass is hydrogen gas. About one fourth of the sun's mass is helium gas.

Thus, while Mrs. Poppy expressed positive APPRECIATION: COMPOSITION for the CDs, stating, "there's just a ton of information" (p. 3), their condensed information was not always sufficient for answering the comprehension questions. For example, during the lesson on moon phases, Mrs. Poppy and the students encountered comprehension questions for which the responses were not included in the worksheets' content. Mrs. Poppy expressed frustration with the lack of information stating, "You don't know any of this yet, but then they throw in a question about it. Does that make any sense to you?" She helped the students to figure out the answers and supplemented the CD worksheets with one from Super Teacher Worksheets© that contained pictures and labels of the various moon phases. Without a curriculum and sufficient materials, Mrs. Poppy became responsible for locating additional instruction materials.

As the only school provisions, the learning tasks in the science instructional materials provided by the school–the worksheets–represent the school's aims for science instruction. Analyzing these tasks according to the revised version of Bloom's Taxonomy (Krathwohl, 2002) shows the cognitive challenges students encounter are at the lowest levels (see Table 4.6).

Table 4.6
Knowledge and Cognitive Demands of Worksheet Tasks

Focus of Tasks	Details	Knowledge Dimension	Cognitive Dimension	Example
Vocabulary	54 words identified by worksheets 9 words defined incidentally 7 different types of tasks (see Appendix D)	Factual Knowledge: Knowledge of Terminology (Aa)	Remember: Recognizing (1.1)	 3. Draw a line from each term to its meaning. Term / Meaning axis — a. the movement of one object around another object rotation — b. the imaginary line that passes through Earth's center and the North and South poles revolution — c. the spinning of Earth
			Remember: Recalling (1.2)	 3. Is the following sentence true or false? Gravity is a force that pushes all objects away from each other. F pulls toward
Comprehension	135 tasks 12 different types of tasks (see Appendix D)	Factual Knowledge (A)	Remember (1.0)	

			Understand (2.0)	**10.** Circle the letter of each sentence that is true about Mars. **a.** Mars is called the "red planet." **b.** There are two moons that orbit Mars. **c.** The surface of Mars is covered with water.
		Conceptual Knowledge (B)	Remember (1.0)	**3.** Is the following sentence true or false? Most of Earth's surface is covered with water. __________
			Understand (2.0)	**5.** The drawing below shows the sun, the moon, and Earth during a solar eclipse. Draw lines from the moon to Earth that show the shadow. 

For example, over the course of 12 lessons from the solar system unit, the worksheets presented and assessed students' ability to define 54 vocabulary words. Mrs. Poppy explained another nine words that appeared incidentally in the worksheets and other texts. Some examples of these words are axis, calendar, neap tide, and umbra. The worksheets presented students with a variety of tasks for practicing and assessing their vocabulary knowledge; nonetheless, the tasks required little cognitive challenge. All of the tasks are classified along the Knowledge dimension at the most basic level, Factual Knowledge (A), specifically Knowledge of Terminology (Aa), and along the Cognitive dimension, the tasks require only that students Remember (1.0)–the lowest level of the taxonomy–by either Recognizing (1.1) or Recalling (1.2). Thus, we see that one of the goals of science education at the school is for students to remember the definitions for science vocabulary words.

The worksheets also prioritized retention and recall of content knowledge, or science facts. As mentioned, students responded to questions on the "Adapted Reading and Study" worksheets as a whole group and on the "Review and Reinforce" worksheets independently. Together with the vocabulary tasks, there were 12 different types of tasks for which students responded (see Appendix C).

Again, the classifications of the worksheet tasks indicate low-level cognitive demands of science facts. In particular, all of the worksheet tasks were classified along the Knowledge dimension as either Factual Knowledge (A) or Conceptual Knowledge (B) and along the Cognitive dimension as either Remember (1.0) or Understand (2.0), the least challenging of the cognitive processes (see Table 4.6).

What we see from the "curriculum" provided by the school is a focus on comprehension and remembering, the two bottom levels of Bloom's Taxonomy, which though important, are not sufficient to meet the disciplinary demands called for in the *Framework* (National Research Council, 2012) and the MSS (MDE, 2015). The materials provided to Mrs. Poppy are designed to work with other materials (e.g., textbooks) to which she did not have access. Moreover, as no other materials supplied support the worksheets, Mrs. Poppy supplements her instruction with information that is readily available and known to her, for example, the Super Teacher Worksheets©.

Teacher Preparation Prepared Mrs. Poppy for Teaching Content and ELA

In addition to school and policy influences, Mrs. Poppy referenced other influences on her instruction. Specifically, at the interview, Mrs. Poppy cited her teacher preparation as playing a role in her current instruction. She explained that she had many science education courses, having had at least one course for each science domain, Earth, physical, and life, and expressed positive JUDGMENT: CAPACITY for her resulting content knowledge: “My classes prepared me for content and how to be knowledgeable in what I’m teaching” (p. 1). My subsequent inquiry about science education courses at the institution where she was certified as a teacher surfaced a university bulletin and the course objectives. According to the bulletin, the science education courses were “designed to give the future teacher a strong conceptual understanding of the life science [Earth/physical] content he/she will be expected to teach” (archived university bulletin). By these accounts, Mrs. Poppy’s preservice preparation courses had the same goals for science education as do her school vis-á-vis its provisions and the GLCEs: understand content.

In addition to my inquiry of her science preparation, I asked Mrs. Poppy about her preservice and graduate literacy preparation. Mrs. Poppy has a strong background in elementary literacy instruction. According to Mrs. Poppy, she had a wealth of literacy education courses, explaining that she had courses on “everything from phonemic awareness...to whole-part-whole versus whole-part-part...to testing...novel units, everything" (p. 1). In addition, as part of her Master's degree program, she participated in the Writing Project, "a four-week long program in which we studied implementing effective literacy into our classrooms" (p. 1). The Master's program also included courses on reading disabilities, current children's literature, and current language arts pedagogy. Mrs. Poppy believes she has been well-prepared to teach elementary English Language Arts (ELA).

Together, Mrs. Poppy's healthy preparation for science content and her strong ELA background align well with school and policy expectations that favor an approach to science that focuses on comprehension of content, or content-area literacy (CAL). In the next section, I explore how accessible resources and professional responsibilities suggest CAL and later, the incongruence of CAL and the MSS (MDE, 2015).

Content-Area Literacy

Content-Area Literacy instruction is a common, text- and teacher-dominate pedagogical approach intended for helping students overcome the difficulties of subject area (i.e., science, social studies, mathematics) texts through explicit instruction in reading skills and vocabulary and with hands-on experiences used to verify information from the texts (Chauvin & Theodore, 2015; Moore, Readence, & Rickelman, 1983). CAL focuses on generalized skills in reading and writing to learn and demonstrate command of subject-area content. According to Jacqueline Barber (2019), CAL instruction is how most of us were taught: "After reading a portion of the textbook, we would listen to the teacher explain what we had read and then respond to questions" (p. 6). In this section, I first discuss the professional responsibilities that engender CAL. Then, I detail the defining characteristics of CAL as observed in Mrs. Poppy's classroom and discussed during our interview. Lastly, I take a deep look at how CAL is enacted in science and how those enactments will need revisions to meet the demands of the MSS (MDE, 2015).

Content-Area Literacy Mediates Constraints and Responsibilities

During the interview, Mrs. Poppy explained that at her school, ELA and mathematics have more priority than do science and social studies. The school's expectations for concentrated ELA instruction is a common response to Michigan's flat reading proficiency scores and the many policies and laws specific to reading outcomes (MDE, 2017). At her school, teachers are encouraged to spend 90 minutes per day on ELA instruction, and all teachers at each grade level are required to teach the same ELA curriculum 80% of the time. Science instruction, on the other hand, lacks similar uniformity and guidance, as teachers make instructional decisions by themselves or amongst their grade-level colleagues.

To mediate the school's priorities and to give students "double of what they need" (p. 2), Mrs. Poppy incorporates ELA into science and vice versa. As she explained, reading and vocabulary are important for comprehending science texts. She further noted that reading science is good ELA practice, "I really think the ELA aspect of it where they're reading in science within ELA, not just within science is important, too" (p. 2). An example of this overlap is Mrs. Poppy's 30-book challenge, for which she challenges students to read 30 books over the course of the school year. As she explained, "[S]tudents have to read multiple genres, like all the genres…some of those are informational texts, so they have to fill those boxes with either science or social studies" (p. 2). Another example is the final project for the animal adaptation unit, which she described during the interview. For this project, students choose a wild animal that is native to the local area and respond to ten questions about that animal, based on the fifth grade GLCEs (MDE, 2007) for science. Then, the students create a project to share those 10 facts about the animal with their classmates. Students are permitted to choose any type of project except posters. Mrs. Poppy encourages the students to “be creative” (p. 6) by presenting their 10 facts in modalities typically associated with ELA, such as poems, songs, and magazines.

Consistent with CAL, these activities foreground ELA activities, specifically, independent reading and creative writing. In contrast, disciplinary literacy, which is expected of the MSS (MDE, 2015), “anchors the disciplines” (Chauvin & Theodore, 2015, p. 1) by focusing on how language and literacy begets scientific knowledge. However, at Mrs. Poppy’s school, where the MSS were not yet adopted, using science texts and content for bolstering reading and writing skills is a means of navigating competing demands for instructional time. Next, I share other details of Mrs. Poppy’s instruction that characterize it as CAL.

Characterizing Content-Area Literacy: Reading to Learn

According to Moore, Readence, and Rickelman (1983), the primary goal of CAL is for students to read to learn by helping “students locate, comprehend, remember, and retrieve information” (p. 420). This instructional goal mirrors that of Mrs. Poppy’s accessible resources, which, as described in previous sections, focus on comprehending content knowledge. This objective also emerged as an instructional focus in the interview and during observations.

Consistent with CAL, Mrs. Poppy shared read-to-learn objectives when asked about the role of reading and writing in science. She expressed intensified positive APPRECIATION: VALUATION for the importance of reading and writing during science instruction, stating that both are of “huge” importance (p. 2) because “students have to be able to understand the content in what they’re reading” (p. 2). To this end, Mrs. Poppy plans instruction around questions the students should be able to answer correctly by the end of the unit. She clarified that these questions are not “Essential Questions” (McTighe & Wiggins, 2013), stating, “it is not one overarching…it's more like four or five big questions that I'm looking for if they're able to answer when we're done [with the unit]" (p. 5). She offered examples from the unit the class had just finished: "For the one we just did [the heredity and genetics unit], it would be *What is genetics?*, *How is it different than heredity?*, *How do adaptations work?*, and *How have fossils shown that animals have evolved over time?* So those are the main things we're focusing on" (p. 5). Decidedly, these questions assess students' recall of content.

Accordingly, Mrs. Poppy plans instructional activities designed to help students understand and recall the answers to the unit questions. The majority of these activities are teacher-led read alouds or explanations of texts during which Mrs. Poppy focuses on general literacy skills for reading to learn–defining vocabulary words, writing notes, highlighting important information, and checking for understanding. She explained her instruction, stating, "We do full-group reading together where I have it up on the screen and they have it in front of them. So, we'll read through and highlight what's important...Any types of notes that we do on the board, they'll put them in their journal and we'll color-code them" (p. 2-3). Mrs. Poppy's attention to these types of generic reading strategies is typical of CAL instruction. In the next section, I describe the extent to which CAL practices conform with disciplinary practices and how the CAL practices can be leveraged in transitioning science instruction from CAL to disciplinary literacy.

The Extent to Which CAL Practices Align with Disciplinary Literacy and Leveraging CAL Practices in Transitioning to a Disciplinary Approach

Content-Area literacy does help students to understand texts by offering generic strategies, but according to Barber (2019), it takes too narrow of a view of the roles of literacy and language in doing science. Nonetheless, the use of these strategies in instruction indicates a value placed on literacy. Therefore, these strategies, reconceptualized by their role in knowledge construction, can be leveraged in transitioning current instruction to disciplinary literacy instruction.

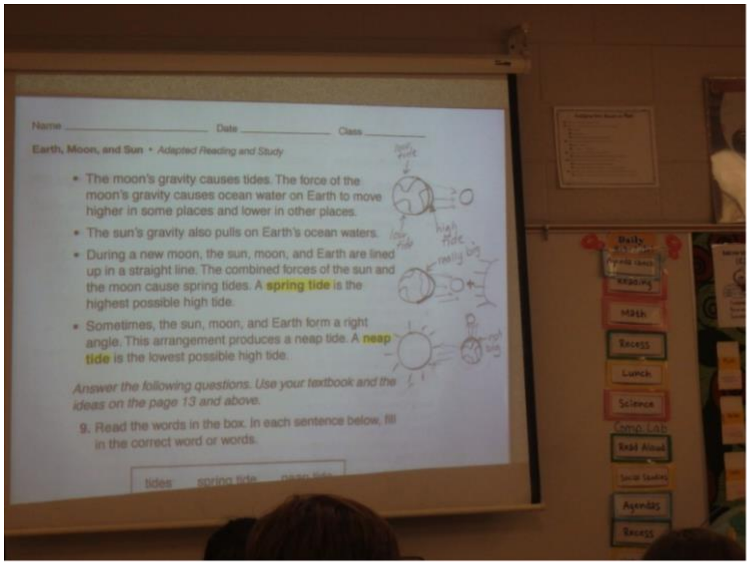
In this section, I describe three comprehension strategies used in Mrs. Poppy's class to help students comprehend texts and the ways in which these tools could contribute to disciplinary literacy instruction.

Visual Representations: Tools for Understanding Versus Tools for Conceptual Thinking

The *Framework* identifies "developing and using models" as a disciplinary practice used to construct scientific knowledge (National Research Council, 2012, p. 42). In this section, I describe the current uses for models in Mrs. Poppy's class and show how they help students comprehend texts.

Mrs. Poppy led the students in drawing many pictures throughout the solar system unit because the worksheets did not contain any visual representations of described phenomena. For example, after reading a section on tides, Mrs. Poppy drew the following diagrams (Figure 4.2) and instructed students to copy the diagrams onto their worksheets.

Figure 4.2
Visual Representation to Aid Comprehension

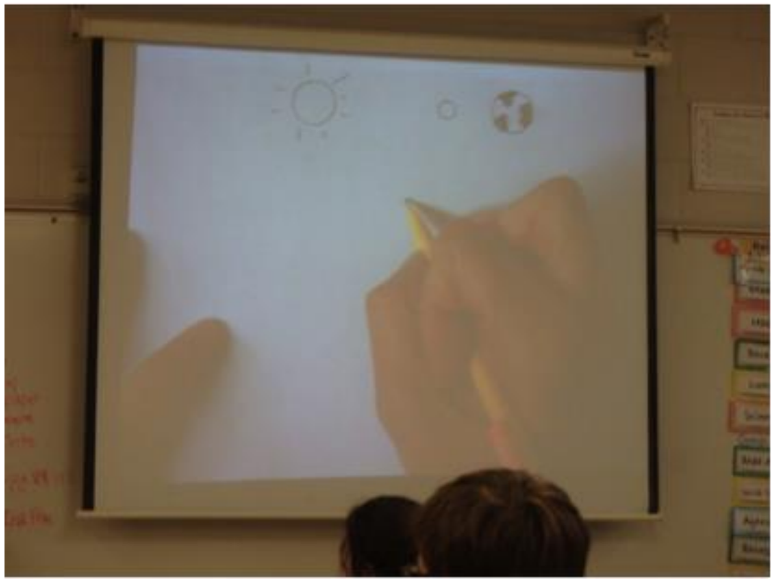


Mrs. Poppy drew the diagram to help the students understand, an important cognitive task, but one at the bottom of Bloom's Taxonomy (Krathwohl, 2002).

Mrs. Poppy also used drawings as a means for assessing students' recall of previously read material. For example, during the lessons on the moon and eclipses, Mrs. Poppy drew one diagram at a time on her worksheet—which was projected using a document camera—and asked the students to collectively label each one.

> T: We learned about a couple of things yesterday. We're going to review those and then we're going to move on. So, I'd like to ask you if you can please tell me, not out loud, please, what this is (Figure 4.3)?

Figure 4.3
Visual Representation to Assess Understanding



S: solar eclipse
T: Solar eclipse. Very good. (8.1)

In this example, Mrs. Poppy asked students to remember (1.0) conceptual knowledge.

Diagrams like these and the others that Mrs. Poppy drew throughout the solar system unit, are representative of diagrams scientists might construct. The difference lies in their cognitive purpose. In Mrs. Poppy's class, as in many elementary science rooms (e.g., Vo, Forbes, Zangori, & Schwarz, 2015), diagrams serve to assist students with understanding and to assess their recall or recognition of concepts. Scientists, on the other hand, create and revise visual representations within an investigation "to better understand a phenomenon" (p. 56). In other words, scientists use visual representations as tools when engaging in higher-order cognitive processes, such as generating (6.1), planning (6.2), and producing (6.3).

The *Framework* (National Research Council, 2012) particularly stresses the importance of student experiences with creating, revising, and critiquing explicit conceptual models that are "analogous to the phenomena they represent" (p. 56). Although students did not engage in creation, revision, or critique, Mrs. Poppy engaged students with demonstrations and an activity that began to approximate authentic uses for analogous scientific models. During the solar system unit, Mrs. Poppy used a globe, a basketball, and a lamp to demonstrate the movement of Earth in space and the resulting phenomena of day and night, seasons, and eclipses. During this demonstration, Mrs. Poppy was explicit that the globe was a model of the Earth:

> T: So, here we have our trusty glove. A globe is a what?
>
> Ss: [multiple responses at once, including sphere and smaller version]
>
> T: A smaller version of Earth. That's also called a…
>
> Ss: [multiple responses at once, including globe and map]
>
> T: [Points to a diorama on display in the classroom] This is a smaller version of a forest. It's a what?
>
> S: model
>
> T: It's a model. So the globe is a model of our Earth, right? (2.1)

However, she was less explicit in explaining that the way she modeled the movement of Earth is akin to scientists' use of models as representations of phenomena that cannot be directly observed. Instead, Mrs. Poppy informally called students' attention to what each object (i.e., the globe, the basketball, and the lamp) represented, stating, "Let's pretend that the sun is over here…" (2.1). To suggest that analogous modeling is synonymous with pretending diminishes the important role of scientific models. Conversely, according to the *Framework* (National Research Council, 2012), curricula should "stress the role of models explicitly… so that students come to value this core practice" (p. 59).

Another emergent approximation occurred during the TSM unit at the end of the penny investigation when Mrs. Poppy asked the students why a scientist might conduct that very same experiment. The students did not know, but Mrs. Poppy offered a practical example of someone who would want to know about how much water could fit on something: "If you have a pool and you have a pool cover and it rains, do you need to care about how much water that pool cover can hold on top of that pool...Do you think that the engineers that build that care about stuff like that" (918.2)? While a scientist certainly could engage in this investigation as a means for understanding some properties of water, the analogy between the pool cover and putting water on a penny and how the penny experiment would inform the pool cover question were not made clear.

While the majority of visual representations were employed as reading comprehension aids, the demonstrations of the Earth's movement in space and the hint at analogous modeling during the penny investigation show that physical modeling is a strategy that Mrs. Poppy could further develop as a disciplinary means for inquiries of science phenomena.

Vocabulary: Knowing Definitions Versus Understanding Concepts

During the interview, Stella expressed intensified positive APPRECIATION: VALUATION for vocabulary instruction, stating, "Vocabulary is very big…vocab[ulary] is so important" (p. 2). Stella's assertion is supported by abundant and clear research about the strong relationship between reading comprehension and vocabulary knowledge (Beck, McKeown, & Kucan, 2013; Blachowicz, 2014; Eunice Kennedy Shriver National Institute of Health and Human Development, 2000). As such, she gave frequent attention to the bolded vocabulary words on the Pearson Prentice Hall worksheets. These key words received the most airtime in her classroom because they were prominent on the worksheets in both the information portions and the comprehension assessments. Matching words and definitions or defining key words were also the most frequently assigned tasks across all of the solar system worksheet sections.

In class, attention to vocabulary served several purposes:

- To review (Remember (1.0)),

T: Yesterday, we talked about what? We talked about this [spins the globe].

Ss: rotation (3.1)

- to check for understanding (Recognizing (1.1)),

  T: All right. Let's take a look at these [number 3]. We're going to match them. The first one, the movement of one object around another object. So, it involves two objects.
  Ss: revolution
  T: The imaginary line that passes through Earth's center and the North and South Poles?
  Ss: axis
  T: Axis. And then, the spinning of Earth, is that rotation?
  Ss: yes.
  T: Good. (4.2)

- and to help students remember (1.0) differences in phenomena:
  - This is how I remember the difference between waxing and waning. When you wax something, it gets clearer and clearer and clearer, right? So, when I think of that, the more that you wax the moon, the more brighter and shinier it's going to get. (8.1)
  - A good way to remember that is if you were to take a picture of the sun, what color would it be? If I take a picture of the sun? Yellow, orange, kind of, right? And when you're seeing that picture, when you are seeing the sun in that photo, you are seeing the photosphere. So, it's a good way to remember that it's the photosphere that you can see. (9.1)

Furthermore, Mrs. Poppy requests students use accurate vocabulary terms during discussions as in this example:

T: So, [bouncy balls] are what shape?

S: circle

T: They are not circles. They are…?

Ss: spheres (918.7)

During my time in her classroom, Mrs. Poppy attended to a total of 72 vocabulary words. Students received a daily work grade for accurately defining or matching 34 of those words and an assessment grade for accurately matching 15 terms and definitions on the solar system unit test. However, because students were rarely tasked with applying new terms in appropriate contexts, as called for by the *Framework* (National Research Council, 2012), students learned definitions but not concepts. According to the American Association for the Advancement of

Science (1990), when teachers put too much focus on defining words, teachers "risk being misled about what students have learned" (p. 203). Such was the case in Mrs. Poppy's class as illustrated in following example.

In the fall, Mrs. Poppy taught a unit on force and motion. Although I did not observe this unit, it was obvious students had become very familiar with the vocabulary words from that unit. For example, Mrs. Poppy passed out the second packet of worksheets, "Gravity and Motion," and asked the students to skim the first two pages to see if there were any words that they had already seen. Students responded with the following words: force, gravity, mass, pull, motion, inertia, and Newton's First Law (5.10). On several occasions, students recited Newton's first law of motion verbatim, and they demonstrated proficiency with defining these reoccurring words as well.

T: Force is what? Go ahead and say it.

Ss: push or pull!

T: Gravity does what?

Ss: attracts an object toward each other!

T: Mass?

Ss: the amount of matter an object has (7.2)

Despite this ability to define words, students did not always understand the concept of the terms. On the third lesson of the "Gravity and Motion" section, the students and Mrs. Poppy corrected the Section Summary and Review and Reinforce portions of the worksheet packet as per the usual pattern. During this episode, it became apparent that knowing the definition was not sufficient for understanding the concept of "inertia" despite the fact the students had learned the definition in the fall and had been reciting it repeatedly over the previous two lessons.

T: Inertia? [What does it mean?]

S: the tendency of an object to not change motion

T: What does that even mean? Raise your hand and tell me. “The tendency of an object to resist its change in motion.” Does that definition help you if you don’t know what it means?

S: no

T: No! It doesn’t. What does this mean, “resist a change in motion”? What does just that part mean? What does “resist” mean?...

S2: try to go in the same direction

T: Not exactly. Good try, though.

S3: to refuse

T: To refuse, what?

S3: to do

T: To refuse to do what? To refuse to do what? To change motion.

S4: to refuse to change motion, slowing down, turning, or speeding up

T: Yes, so if something is already in motion, what does it want to do?

S5: stay in motion

T: It tends to keep going, right? What if something’s motion is stopped? If their motion is stopped, they want to do what?

Ss: stop

T: Well, a ball can’t really want to do anything, can it? So, that’s why we say “tendency.” Instead of saying “they want to do it,” we say, “the tendency.” So, it tends to stay there unless acted on by what? (7.2)

This excerpt highlights another reason the conceptualization of science as content to recall and understand is problematic: Correct definitions are interpreted as mastery of recall.

Mrs. Poppy understands the importance of vocabulary instruction. However, unlike vocabulary words found in narrative texts, science words are not easily understood through context clues or by providing synonyms. Science vocabulary is technical (Fang, 2005) and conceptually complex (Hiebert & Cervetti, 2012). The goal for vocabulary instruction in science is not to simply define words but to understand the concepts for which the words represent. Therefore, according to Cervetti, Hiebert, Pearson, & McClung (2015), new words must be explicitly defined and "bound to hands-on scientific investigations" (p. 12). To learn vocabulary in meaningful ways in a disciplinary context, students will need opportunities to discuss the concepts represented by the words and experience the concepts firsthand.

Background Knowledge: Everyday Versus Scientific

According to the *Framework* (NATIONAL RESEARCH COUNCIL, 2012) a hypothesis "is made based on existing theoretical understanding relevant to the situation and often also on a specific model for the system in question" (p. 67). As Galus (2003) stressed, hypotheses are formulated only after much observation, calculating, studying, and research. In other words, hypotheses require significant, relevant background knowledge. In this section, I show how Mrs. Poppy activates students' background knowledge to support their comprehension. Then, I show the nuances of background knowledge in formulating a hypothesis.

During the interview, Stella expressed APPRECIATION: CAPACITY for her instruction because she calls upon students' background knowledge, knowing that "if they have experienced it, they have knowledge about it and then they can share it" (p. 2). Stella was correct; results of many studies throughout many decades suggest the activation of prior knowledge to be particularly useful with expository text reading (e.g., Coté, Goldman, & Saul, 1998; Laing & Kamhi, 2002; Lipson, 1983; Schellings, Aarnoutse, & van Leeuwe, 2006; Taylor, 1979). During observations, I witnessed the many ways in which she engaged students' schemata when reading content texts, including:

- priming students' background knowledge prior to the presentation of new information,
    - "We have rotation, and we have revolution. You will be required to know the difference between them. And some of you might already know that because you did learn about that last year" (2.1).
    - "Think about our summer. How much of our day is daylight" (3.1)?
    - "Last year, did you do anything with the scientific method" (912.1)?
- relating information from the science texts to other texts with which students had previously engaged,
    - "Remember that video we watched where the moon went in front of the sun and it was like that diamond ring effect, that just lit up and you could just see that hazy part" (9.1)?
    - T: Venus was the ancient Greek and Roman goddess of love. Venus was her Roman name while the Greeks knew her as…Does anyone know? Do I have some, oh, what books is it that has all the Greeks and Romans? What's that series of books?

      S: Percy Jackson

      T: Percy Jackson and the Heroes of Olympus [book series by Rick Riordan], anybody read those? It was Aphrodite (10.1).

      T: In Alaska, Native people once believed that a raven made the land by diving into the ocean and bringing up a clump of mud in its beak. An alternative version of this myth describes how a coyote created the land from a floating bird's nest. Do you remember in *The Birchbark Hous*e [a book by Louise Erdich]?

      Ss: Yeah!

      T: and what was it that went down?

      S: a muskrat! (10.2)
- and asking about students' prior experiences with phenomena under study,
    - "How many of you have ever seen them [eclipses]? Even if it's just a partial eclipse, have you ever seen one" (7.6)?
    - "We're going to talk about the tides. How many of you have got to experience tides? That you've been able to go to the oceans and see this" (8.2)?
    - "Has anyone ever gotten the opportunity to go to a meteor crater before and see a crater that has been caused from that" (12.5)?
    - "Has anyone in here ever done a little science experiment, like where you grew a plant or anything like that" (913.1)?

As evident, Mrs. Poppy was true to her word; she regularly prompts students to think about or share background information relevant to the content of the texts they were reading.

While general familiarity with a phenomenon can help students to comprehend science texts, hypothesizing requires specialized background knowledge. The following episode shows that Mrs. Poppy and the students are not sure what background knowledge counts when gathering information to form a hypothesis:

> T: I just want to know, tell me anything that comes to mind about a bouncy ball. They are this. They do this" (918.6)
> …
>
> S: The weight of the bouncy ball, that how it's controlled by weight distribution.
>
> T: What do you mean?
> …
>
> S: And if there's a lot of weight behind it, sometimes that gives it more speed and more power to get back up.
>
> T: So, you're saying if it weighs more, it will have more speed when it bounces. Okay. So, does that mean that the big ones, the big bouncy balls, will bounce higher than those little ones, because they weigh more?
>
> S: Not always, but most of the time, yes.
>
> T: Okay, I beg to differ because I think that if it's heavier, those big ones, they don't tend to bounce as high. The lighter ones do, from my past experience, but I could be wrong. (918.6)

The second student to contribute stated that bouncy balls are made of rubber. Mrs. Poppy added that information to the investigation sheet. However, the third student's prior knowledge was again incongruent with Mrs. Poppy's intentions.

> S: [I]n my past experiences, the smaller ones, when I throw them harder, they bounce all over the place.
>
> T: So, you think the smaller, they'll bounce higher or harder. Okay? We would have to test that to make sure, and everything I want here, I don't want to have to test it. I want this to be all of our prior knowledge, not what we think…I think in order to prove what either of you are saying, we'd have to try it. So, let's stick to more basic facts about bouncy balls, something like they are made of rubber, okay? (918.6)

This same scenario repeated several more times as students attempted to contribute facts they thought to be true about bouncy balls (i.e., they cannot bounce if they are frozen; they bounce lower if they are thicker; if a bouncy ball is heated up, it will turn into Play-doh). Eventually Mrs. Poppy prompted students to provide information suitable for inclusion on the investigation sheet and she summarized the information into a concise paragraph:

> They are made of rubber. They come in many sizes. They bounce at different heights depending on the circumstance. They are spheres that bounce. They have a solid center. They come in different colors. If you throw it, it will bounce back. (918)

These episodes within the bouncy ball investigation illustrate Mrs. Poppy and the students' varied understandings of background information within the context of an investigation. Some students seemed to accurately understand that background knowledge relevant to the research question should contribute to understanding the relationship between characteristics of the bouncy ball and the drop height. Other students seemingly understood that the solicitation of background knowledge did not mean they should share just any experience with bouncy balls but rather background knowledge that seemed scientific, even if they were not sure their contributions were true.

Background knowledge is important to comprehension and to learning new information, such as science concepts. Mrs. Poppy can advance her practices with background knowledge by engaging students in activities that build background knowledge. The penny investigation, for example, could help build background knowledge about the properties of water. Bouncing the bouncy balls could build background for understanding how they bounce. These experiences can then be leveraged in initial explanations of other phenomena.

Content-area literacy instruction encourages students to engage in generic comprehension strategies for the purpose of understanding content-area texts. In Mrs. Poppy's classroom, CAL meant creating visual representations, attending to vocabulary, and activating background knowledge, practices that both advanced and obscured authentic engagement in science. However, these current practices can be leveraged in helping to move instruction toward disciplinary literacy.

Chapter Summary

Mrs. Poppy is a rural fifth-grade science teacher who is attentive to her professional obligations and whose instructional practices are crafted from her experiences in her teacher preparation program, the GLCEs (MDE, 2007) for which she is responsible, and the worksheets provided by the school, as well as the school's predilection for ELA instruction. These resources and expectations position science as a set of disciplines comprised of a discrete facts that are learned through low-level cognitive tasks of recalling and understanding content and procedural knowledge. In adhering to this conception, Mrs. Poppy enacts instruction that is best described as content-area literacy, an approach to science instruction that does not conform to the expectations of the state's newest standards, the Michigan Science Standards (MDE, 2015).

The newest standards, the Michigan Science Standards (MDE, 2015), on the other hand, expunge CAL in advocating for disciplinary literacy instruction. Disciplinary literacy instruction is a markedly different approach to teaching and learning, and therefore, Mrs. Poppy–and other teachers making the transition–will need support to enact instruction consistent with the intent of the MSS. Leveraging teachers' current instructional practices is a way to help transition instruction toward disciplinary literacy instruction while respecting the teachers' experiences and importantly, the pedagogical context.

CHAPTER V

Supporting Teachers to Develop Disciplinary Literacy: Implications and Discussion of the Findings

Introduction

In 2015, Michigan made profound conceptual and instructional changes to science education with the adoption of the Next Generation Science Standards (NGSS Lead States, 2013), adopted as the Michigan Science Standards (MSS; Michigan Department of Education [MDE], 2015). Unlike previous standards structured around science content knowledge, the MSS call for disciplinary literacy, which attends to both content and the discipline-specific literacy practices that produce and revise scientific knowledge (Moje, 2008). At the forefront of this reform are the teachers tasked with realizing the new vision for science education for whom professional development will be critical for bridging the gap between their current instructional practices and those called for in the MSS (Allen & Penuel, 2015; Birman, Desimone, Porter, & Garet, 2000, p. 28).

Keenly aware of the need for coherent professional development responsive to the NGSS and other similar standards, the Board on Science Education worked with the Teacher Advisory Council of the Academies Foundation to study how to best provide support for science teachers undertaking the new standards. The committee's report, *Teacher's Learning: Enhancing Opportunities, Creating Supportive Contexts* (National Academies of Sciences, Engineering, and Medicine, 2015), details 13 conclusions about teacher learning and makes seven recommendations for practice and policy and six recommendations for additional research. Among those conclusions and recommendations is a recurrent call for professional development designed to build individual teacher capacity for science teaching. For example, the committee found that currently in research literature there is little attention "to offering teachers learning opportunities tailored to their specific needs" (Conclusion 3, p. 215). In Recommendation 2, the committee suggests that professional development should "attend to teachers' individual and context-specific needs" (p. 222). In this chapter, I extrapolate case study data on the individual and context-specific needs of an elementary science teacher and apply the construct of Zone of Feasible Innovation (Rogan, 2007), drawn from Vygotsky's Zone of Proximal Development (Vygotsky, 1978), in order to propose a scaffolded set of instructional strategies designed to bridge current instructional practices with those required by the Michigan Science Standards (MDE, 2015).

I begin this chapter with a review of the literature on professional development, echoing the National Academies of Sciences, Engineering, and Medicine's (2015) call for differentiated professional development.

Features of Effective Professional Development for Achieving the Goals of Educational Reforms

Timperley, Wilson, Barrar, and Fung (2007) define professional development as "the dissemination of information to teachers in order to influence practice" (p. 284). Ideally, professional development involves professional learning, or the "internal process by which individuals create professional knowledge" (p. 284). Professional development (PD) can take many forms from traditional workshops, conferences, and courses to "reform types" (Desimone, Porter, Garet, Yoon, & Birman, 2002, p. 82), such as study groups, mentoring, and self-study.

In this century, research on PD is of great interest, but prior to and in the early 1990s, professional development research largely considered teacher reports of satisfaction with the content and design of professional learning opportunities as the measure for effective professional development. While this continues to be the prominent measure for locally-offered professional development, since the late 1990s, mainstream research on professional development has taken a process-product approach, exploring whether the process, the professional development, results in the desired products, teacher knowledge, teacher change, and positive student outcomes (Desimone, 2011; Hill, Beisiegel, & Jacob, 2013). Much of this research compares various design features of professional development, such as its duration, or interactions among features, with measures of teacher change, commonly student assessments and teacher evaluations.

Darling-Hammond, Hyler, and Gardner (2017) reviewed 35 "methodologically rigorous studies" (p. v) that indicated a positive relationship between teacher PD, teaching practice, and student outcomes to determine common features of effective professional development. Analysis indicated that effective PD incorporates most or all of the following seven features: is content-focused, engages teachers in active learning, supports collaboration, uses models of effective practice, provides coaching and expert support, offers feedback and reflection, and is of sustained duration. In this section, I consider these features across findings from seven additional large studies (see Table 5.1) and in conversation with smaller studies, synthesizing what is known about the extent to which each design feature can contribute to effective professional development.

Table 5.1
Methods of Studies Included in Synthesis of Research on Features of Effective PD

Study	Methods
Birman, Desimone, Porter, & Garet (2000)	Surveyed nationally representative sample of U. S. teachers of 1000+ teachers who participated in PD funded in part through a federal program
Desimone, Porter, Garet, Yoon, & Birman (2002)	Surveyed purposefully selected sample of U. S. teachers from 30 schools in 10 districts in 5 states over three-years; analysis done for teachers who returned surveys for all three years (N=207)
Ingvarson, Meiers, & Beavis (2005)	Review of 4 evaluation studies conducted by Australian Council for Educational Research; in total data were gathered from 3250 teachers who participated in over 80 different PD programs
Timperley, Wilson, Barrar, & Fung (2007)	Meta-analysis of 72 studies of professional development that contained statistical data for student outcomes
Wei, Darling-Hammond, & Adamson (2010)	Survey of 35,800 U. S. teachers to gather data on characteristics and qualifications of principals and teachers; school hiring practices, teacher PD, and more
Kennedy (2016)	Review of experimental studies of PD for K-12 U. S. teachers of core academic subjects published since 1975 that met 5 criteria: study was only about PD, study included evidence of student achievement, study designs controlled for teachers' motivation for learning, study duration was at least 1 year, and researchers followed the teachers (not students) over time
Kraft & Blazar (2018)	Meta-analysis of 60 studies evaluating the effects of professional coaching; studies were either randomized controlled trials or quasi-experimental research designs that isolated the effect of coaching and linked coaching to positive teacher practice and student achievement

Is Content-Focused

Effective professional development is content-focused (Birman et al., 2000; Darling-Hammond et al., 2017; Desimone et al., 2002), building teacher proficiency in content knowledge for a specific subject area, how students learn content in that subject area, and knowledge of methods for teaching the content (Ingvarson, et al., 2005). Ingvarson et al. (2005) found that a content-specific focus is the most important influence on increased teacher knowledge while Desimone et al. (2002) found that the relationship between teachers' implementation of practices in the classroom and professional development that focuses on a specific practice or set of practices and has other features of high-quality PD is positive but not statistically significant. One reason for the contradictory findings might be that, as Kennedy's (2016) analyses indicated, PD programs that focus exclusively on content are less effective at achieving positive student outcomes than programs that embed content within a larger goal, such as learning how to engage students in sense-making.

Engages Teachers in Active Learning

"Sit and get" (Kraft & Blazar, 2018, p. 70) professional development in which teachers listen to lectures–the form of professional development most prominent in PD research from the United States–is not sufficient for helping teachers to understand content (Timperley et al., 2007) because it only attends to what teachers must learn and not how teachers learn (Darling-Hammond et al., 2017). Effective professional development, on the other hand, attends to both and engages participating teachers in active learning (Birman et al., 20000; Darling-Hammond et al., 2017; Desimone et al., 2002; Ingvarson et al., 2005; Masuda, Ebersole, & Barrett, 2013). Active learning activities, such as trying specific strategies and looking at teaching artifacts, should be aligned with the content goals and should be sequenced to support teacher understanding of the relationship between teaching and learning. According to Timperley et al. (2007), the typical sequence begins with a rationale or catalyst for participating in the PD followed by instruction in the theoretical underpinnings of the desired changes, and ends with opportunities for teachers to "translate theory into practice" (p. xxxvi).

Ingvarson et al. (2005) found that save content knowledge, active learning and teacher reflection have the most influence on teacher practice outcomes across all four of the programs they studied, and the interaction between active learning and outcomes is statistically significant.

Desimone et al., (2002) found a significant increase in teachers' use of a particular strategy when teachers have opportunities to practice the strategy during PD.

Supports Collaboration

According to Darling-Hammond et al., (2017), "High quality PD creates space for teachers to share ideas and collaborate in their learning, often in job-embedded contexts" (p. v). Learning in job-embedded contexts is important because it allows for teachers from the same grade level, content area, or school to work collectively, which is shown to have a significant effect on teachers' use of a particular reform strategy (Desimone et al., 2002) and contribute to a shared understanding of professional goals (Birman et al., 2000). Timperley et al. (2007) assert that effective collaborative communities share two characteristics. First, participants are supported in processing new understandings and their implications, which sometimes involves discursive negotiation to challenge existing understandings and make sense of new ideas. Secondly, the community focuses on how teaching impacts student learning.

One way a collaborative community can focus on student learning is through collaborative evaluations of student work, which Ingvarson et al. (2005) argue is critical for effective professional learning because it "de-privatise[s]" teacher practice, allowing for colleagues to learn from one another (p. 9). Furthermore, collaborative evaluations of student work lead to "deeper understanding of student learning outcomes and greater discrimination about what counts as meeting those objectives" (p. 9). Overall, Ingvarson et al. (2005) found collaboration to have a significant impact on both teacher knowledge and teacher practice.

According to Kennedy (2016), however, the relationship between collaboration and positive outcomes is not consistently positive. In comparing the effectiveness of professional development programs structured around professional learning communities, Kennedy (2016) found mixed results. In fact, participation in one professional learning community actually had a negative effect on student learning. Kennedy (2016) cautions that professional learning communities, as a structure for collaboration, are effective relative to the content the groups discuss and "the nature of the intellectual work they are engaged in" (p. 972).

Uses Models of Effective Practice

High-quality professional development includes models of best practices, or what Ball (1996) refers to as "models of reform" (p. 507). These models, including models of lesson or unit plans, sample student work, peer observations, video footage of teaching, or written scenarios (Darling-Hammond et al., 2017, p. v) provide teachers with explicit illustrations of effective practices in use. According to results from a survey of 258 teachers from 42 states regarding their perceptions of online professional development, the most popular activity–the activity online professional development participants found the most beneficial–is accessing videos of exemplary instruction from a video library (Parsons et al., 2019). Videos allow for teachers to see the feasibility and reality of best practices in classroom contexts upon which they can "anchor their own learning and growth" (Darling-Hammond et al., 2017, p. 11). Kennedy (2016), however, found that it is not the models alone that contribute to changes in teacher practice and improved student learning but rather the dialogue and sense-making regarding the practices observed in the models that contributes to positive outcomes. Therefore, models of effective practice contribute to positive outcomes when they are combined with other features of high-quality PD, such as collaboration, active learning, feedback, and reflection.

Offers Feedback and Reflection

Effective professional development allots time for teachers to reflect upon, think about, and receive feedback on their practice and their progress toward best practices (Ball, 1996;

Darling-Hammond et al., 2017; Ingvarson et al., 2005). Ingvarson et al. (2005) found the extent to which professional development provides follow-up feedback during the implementation phase significantly impacts teacher knowledge. Interestingly, Parsons et al. (2019) found that none of teachers' preferable formats of online professional development included feedback. Kennedy's (2016) findings offer a possible reason for this preference. When feedback is presented as evaluative, professional development is less effective in achieving positive outcomes than when feedback is offered as a collaborative, problem-solving approach toward strategic instruction. It is possible that teachers feel the feedback offered in online PD formats is evaluative and not particularly helpful.

Provides Coaching and Expert Support

Likewise, according to Darling-Hammond et al. (2017), effective professional development involves the sharing of expertise regarding content and best practices through professional coaching and expert support (Darling-Hammond et al., 2017). One form of professional development that encompasses both of these features is professional coaching. Professional coaching is an increasingly common form of job-embedded, differentiated professional development (Grierson & Woloshyn, 2013) characterized by Kraft and Blazar (2018) as "an observation and feedback cycle in which coaches model research-based practices and work with teachers to incorporate these practices into their classrooms" (p. 70); it is "individualized, time-intensive, context-specific and focused on discrete skills" (p. 70). Professional coaching weaves all characteristics that have already been established as features of effective PD into a PD model based on individual teacher needs. Kraft and Blazar's (2018) meta-analysis indicated an improvement in the quality of teachers' instruction as a result of professional coaching equal to the difference in effectiveness between a new teacher and a veteran teacher of five to ten years. Darling-Hammond et al. (2017) found that teachers who participate in coaching are more likely to implement reform-based practices and enact them more appropriately than are teachers who receive more traditional forms of professional development.

Timperley et al. (2007) found that involvement of external expertise was a feature of almost all core studies likely because reform efforts require not just understanding new standards but new content, skills, and habit of minds. In order to contribute to positive outcomes, however, experts must have provider pedagogical content knowledge, or knowledge of how to "make the content meaningful to teachers and manageable within the context of teaching practice" (p. xxix). However, external expertise is not always feasible because it usually requires additional funding. For this reason, internal coaching and small group workshops are appealing options because teachers with a variety of backgrounds and expertise can serve the role of expert (Darling-Hammond et al., 2017).

Is of Sustained Duration

Changes in teacher knowledge and practices and student achievement are difficult (Timperley et al., 2007) and do not happen overnight (Ball, 1996); they are "slow and incremental"(Kennedy, 2016, p. 973). Therefore, quality professional development, according to Darling-Hammond et al. (2017), "provides teachers with adequate time to learn, practice, implement, and reflect upon new strategies that facilitate changes in their practice" (p. vi). However, across the studies reviewed here, there are varying definitions of "adequate." According to Wei et al., 2010, adequate PD has an annual duration of 45 – 300 hours. For Desimone (2011), high-quality professional development requires 20 or more contact hours spread over a semester. Other research (Birman et al., 2000; Ingvarson et al., 2005; Kennedy, 2016; Timperley et al., 2007) has found that the duration of the PD is not a reliable feature of effectiveness. Rather, programs of longer duration or higher intensity typically also have more content-focus and opportunities for active learning. Thus, their research suggests that how PD time is used is more positively related to positive outcomes than is duration.

Summary of Features of Effective Professional Development

In general, high-quality professional learning occurs when teachers have sufficient time to develop content knowledge and teaching strategies for teaching content through job-embedded professional development. Effective PD embeds content into larger instructional goals and provides teachers with opportunities to engage in collaborative, active learning that allows for practice and the sharing of expertise. Effective PD also includes iterative cycles of observations and practice, feedback, and reflection.

However, the above synthesis also indicates that these design features do not ensure the success of professional development opportunities. For example, as described above, even though some research considers feedback a feature of effective PD (Ball, 1996; Darling-Hammond et al., 2017; Ingvarson et al., 2005), other research shows that teachers do not always want or find value in feedback (Parsons et al., 2019). According to Kennedy (2016), the variability of the impact of specific design features suggests we need a different conception of PD, one “that is based on more nuanced understanding of what teachers do, what motivates them, and how they learn and grow” (p. 974). Therefore, in the next section I argue that effective professional development requires what Timperley et al. 2007 refer to as “effective contexts” (p. xxxvii) and that in order for professional development to be effective and result in positive outcomes relative to the goals of the MSS (MDE, 2015), it is necessary to have a thorough understanding of the affordances and constraints of the context in which the standards and PD are to be enacted. In accordance with the National Academies of Sciences, Engineering, and

Medicine (2015) professional development must attend to the teachers' individual and context-specific needs.

Contexts that Limit and Support Professional Learning

Even well-designed professional development is not guaranteed to produce positive outcomes because contextual factors can inhibit or limit the realization of the goals for professional development. According to Darling-Hammond et al. (2017) possible contextual barriers include "lack of shared vision about what high-quality instruction entails" and "conflicting requirements, such as scripted curriculum or pacing guides" (p. 24). This was the case for a teacher in Allen and Penuel's (2015) multi-case study exploring teachers' responses to professional development aimed at supporting teachers in implementing the NGSS (NGSS Lead States, 2013). In the first year of the study, professional development focused on understanding the tenets of the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012), and the second year focused on the NGSS (NGSS Lead States, 2013) and project-based inquiry science curriculum. The researchers found that sources of ambiguity and uncertainty influenced teachers' perceptions of the extent to which the professional development aligned with the goals for science teaching and learning within their contexts. The most common source of ambiguity and uncertainty was conflicting ideas about the nature of high-quality science instruction. For example, during a lesson on energy, the teacher had students explore a variety of toys with various springs and contraptions. While the teacher's goal was to engage students in the scientific practices of observation and hypothesizing, the administration thought the lesson lacked rigor. Likewise, the study found that "tools and routines increasingly common in schools as devices for 'tightening' the coupling of policy and practice," (p. 147) such as standardized lesson planning templates and requirements for all teachers to teach the same lesson every day, actually created ambiguity between the goals presented in professional development and the school's expectations for its teachers.

In contrast, contexts conducive to professional learning are consistent with wider trends in policy and research (Timperley et al., 2007). This consistency is also known as coherence. According to Birman et al. (2000),

> Coherence indicates the extent to which professional development experiences are part of an integrated program of teacher learning–activities that are consistent with teacher goals, build on earlier activities, are followed by additional activities, and involve teachers in discussing their experiences with other teachers and administrators in the school. Activities are coherent when they support national, state, and district standards and assessments. (p. 31)

Coherence is associated with increased teacher learning and improved classroom practice (Birman et al., 2000). Therefore, effective professional development must cohere with context-specific goals and policies.

Teachers' needs are rarely considered in decisions about professional development offerings (Darling-Hammond, et al., 2017), but according to Korthagen (2017), "attempts at influencing teacher behaviour have to be adjusted to individual teachers in their specific circumstances and settings" (p. 393). For example, teachers may lack or have inadequate materials and curriculum resources, problematic prevailing discourses, or other instructional obstacles. Professional development that offers "differentiation of opportunity" (Allen & Penuel, 2015, p. 147) accounts for these context-specific sources of conflict and uncertainty. A study by Grierson and Woloshyn (2013) illustrates the potential of professional learning when teachers' personal and contextual needs are considered.

Grierson and Woloshyn (2013) conducted a qualitative case study of three elementary teachers who wanted support with student assessments. Each teacher had different skills or practices she wanted to understand or revise. For example, one teacher wanted to improve her assessment strategies while another teacher wanted strategies for enacting effective instruction of story elements, a need identified by assessments. Professional learning activities designed to address their individual needs and participation in a small professional learning community focused on assessments, and instructional coaching supported teachers in improving their practice and enhanced their self-efficacy for teaching. One year after this initiative, the changes the teachers made were sustained, and the participating teachers had assumed leadership roles in leading needs-based professional learning opportunities for their colleagues, thereby building internal capacity for change.

In this section, I showed that contexts either support or impede the effectiveness of professional learning and change. Professional development opportunities that do not address teachers' individual and context-specific needs will likely fail to achieve the coherence necessary to improve teacher practice and student outcomes (Hill, 2009). However, when teachers' needs are considered in the design and enactment of professional learning opportunities, contexts are not a barrier to adopting reform-based practices. Teachers like Mrs. Poppy need and deserve these types of professional learning opportunities for supporting their implementation of the MSS (MDE, 2015). However, research on differentiated professional development for science is scarce (National Academies of Sciences, Engineering, and Medicine, 2015).

In the remainder of the chapter, I contribute to this gap in knowledge by proposing a research-based, context-specific approach for leveraging current instructional practices in elementary science teaching. The approach is tailored to cohere with existing resources and teacher practices and scaffolded toward the literacy instruction required by the MSS (MDE, 2015).

Leveraging Current Instructional Practices to Achieve Disciplinary Literacy Instruction in a Fifth Grade Classroom

In this case study, I explored the pedagogical resources and constraints that shape–and are shaped by–the instructional practices in Mrs. Poppy's rural fifth grade science classroom and the extent to which those practices conform with a disciplinary approach to science as required by the MSS. Mrs. Poppy's instruction is constrained by not having a science curriculum or curriculum materials, the school's haphazard organization for science instruction, and policies and expectations that privilege English language arts instruction while limiting instructional time for science. Her instruction is further limited by her accessible resources. These resources, her own understanding of science developed through her preservice education courses and the worksheets–provided by the school–around which Mrs. Poppy structures her instruction, present a conceptualization of science as a body of knowledge. This conceptualization aligns with the requirements of the previous state standards, the Grade Level Content Expectations (GLCEs; MDE, 2007) for science, for which she is responsible and uses as an instructional guide. As the overarching goals for science education in the state, the GLCEs identified understanding conceptual and procedural knowledge as the primary objective. Accordingly, Mrs. Poppy enacts instruction designed to support students' comprehension and recall of science texts and content, instruction characterized as content-area literacy.

A content-area literacy approach to science instruction assumes a narrow understanding of the role of literacy in doing science, posturing written texts as the locus of scientific knowledge and neglecting the "reasoning, argumentation, and inquiry that shape literacy practices in the disciplines" (Barber, 2019, p. 7). Therefore, content-area literacy instruction for science is incongruent with the disciplinary literacy demands of the new standards.

To transition from the content-area literary approach to a disciplinary literacy approach, teachers like Mrs. Poppy will need professional learning opportunities that are responsive to the resources and constraints of their contexts and their current instructional practices. To fill this need and to contribute to the need for better understanding of differentiated professional development, I apply the construct of zone of feasible innovation (Rogan, 2007) to propose a set of scaffolded strategies designed to incrementally evolve practice from content-area literacy to the disciplinary literacy required of the MSS (MDE, 2015). This approach to professional learning assumes a social constructivist theory of learning.

Social constructivism is a learning theory grounded in the viewpoint that learning happens through the active mental engagement of integrating old knowledge with new knowledge through guided scaffolding (Tracey & Morrow, 2012). While *scaffolding* has come to mean many different things, a common feature is that scaffolding involves a determination of learners' current levels of performance (van de Pol, Volman, & Beishuizen, 2010). Once a level of performance has been determined a more knowledgeable other matches the level with learning activities that will promote development. Vygotsky (1978) calls the distance between a learner's developmental level and the level attainable the *zone of proximal development* (p. 86).

Rogan (2007) applies Vygotsky's concept to the development of teacher practice, proposing a construct he calls, the *zone of feasible innovation* (ZFI). According to Rogan (2007), a ZFI is "a collection of teaching strategies that go beyond current practice, but are feasible given the existing resources available to that teacher" (p. 441). The ZFI exists along a continuum of practice bounded on the left by practices that are currently routine and on the right by the ideal (reform) practices (see Figure 5.1). These boundaries are dynamic; as new strategies become routine, the boundaries shift to the right. Teachers who have high levels of support can move the upper boundary farther and farther to the right.

Figure 5.1
Location of ZFI on a Continuum (Rogan, 2007, p. 450)

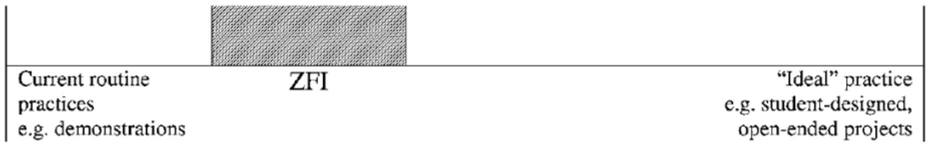


Figure 1. The location of a ZFI on a continuum.

Identifying a ZFI might be a useful construct for supporting the development of teachers' instructional practices toward instruction consistent with the vision of the NGSS (NGSS Lead States, 2013) and the MSS (MDE, 2015). I explore this possibility by detailing the process by which I identified two potential zones of feasible innovation for Mrs. Poppy. I present the identification and development of these zones as a model for how this process could be employed in designing differentiated professional development for supporting other teachers tasked with enacting new practices.

Finding Zones of Feasible Innovation

According to Rogan (2007), the first step in designing a ZFI continuum is to consider the capacities of the context, for "the continuum needs to be rooted in reality" (p. 452) by determining boundaries that account for all the forces that influence implementation and that are feasible at this particular point in time. Thus, in designing continua for Mrs. Poppy, I consider no more or less than the provisions available at the time of observations. Recall that Mrs. Poppy does not have textbooks, teachers' manuals, or even a science curriculum. Her school has not provided any professional development or resources for implementing the new MSS (MDE, 2015) and in fact, for that reason had not yet adopted them. Her only provision from the school was a set of CDs from which she could print student worksheets that were aligned with the previous standards, the GLCEs (MDE, 2007). The left, or lower boundary of each continuum starts with practices I observed during the scientific method and solar system units and that are compatible with ideal practices. In choosing practices for the right, or upper, boundaries, I referred to practices detailed in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NATIONAL RESEARCH COUNCIL, 2012; hereafter referred to as the *Framework*) and the National Research Council's (2015) recommendations for implementing the new science standards, selecting those are attainable given the available resources.

The second step is to identify and sequence feasible "concrete classroom strategies" (Rogan, 2007, p. 453) that will transition from current to ideal practices. In the remainder of this chapter, I describe two zones of feasible innovation designed to scaffold Mrs. Poppy's teaching from content-area literacy instruction and practices that focus on developing students' general literacy skills and content knowledge to instruction that engages students in the disciplinary literacy practices called for in the MSS (MDE, 2015). I present each ZFI and offer a rationale for its potential efficacy. Then, I explore how Mrs. Poppy's proficiencies with current practices make the ideal practice a reasonable aim. To do this, I report on the ways Mrs. Poppy enacted the content-area literacy strategies that the ZFI is designed to enhance with disciplinary perspectives and practices. Finally, I explain proposed classroom strategies–drawn from research literature–for scaffolding Mrs. Poppy's instruction from the lower boundary to the upper boundary.

ZFI: From I-R-E to Collaborative Sense-Making

As established in previous chapters, the objectives for fifth grade science identified in the GLCEs (MDE, 2007) call for students to comprehend presented content, and accordingly, Mrs. Poppy's current instruction is structured around the presentation of the required content and assessments of comprehension, which has led to text- and teacher-dominated discussion, as described in the vignette in chapter one. In contrast, as also previously noted, the MSS (MDE, 2015) call for students to be agentive in their learning, echoing the NRC's (2015) call for students to be engaged in "collaborative sense-making" (p. 30). Thus, there is an articulate expectation for change, and therefore, I propose the following ZFI (Figure 5.2) designed to support a transition from teacher-dominated to student-directed discussions.

Figure 5.2
ZFI for Collaborative Sense-making

The lower boundary starts with the current practice of teacher-directed cycles of I-R-E, initiate-respond-evaluate (Ruiz-Primo & Furtak, 2007). Within teacher-dominated discussion, teachers ask, or initiate questions to gauge and encourage students' comprehension. Students respond, and the teacher evaluates the accuracy of the response. I-R-E cycles are the cornerstone of classroom talk in Mrs. Poppy's classroom and typical of many science classrooms (Windschitl, 2019). The following excerpt from a lesson on the causes of night and day illustrates a typical I-R-E cycle in Mrs. Poppy's class.

> T: When will be the longest day of the year? When it comes up the earliest and doesn't go down until the latest?
>
> Ss: [multiple responses]
>
> T: Not the 27th, not the 18th
>
> S: the 21st?

T: The 21st of June. How close are we to that?

S: close

T: We're very close to June 21st. We're only like a month and a half away from that.
…

T: And then what happens after June 21st?

Ss: goes down

T: Yeah, the amount of daylight hours starts going down. It gets shorter and shorter, until what day? What's the shortest?

S2: September 21st!

T: Nope. Good try. What would be the opposite of June? The opposite of June. Hand on your head when you know. What would be the opposite month of June?

Ss: [no response]

T: How many months are there in a year?

Ss: 12

T: What's half of that?

Ss: Six.

T: So, count six months from June. [Student], what would it be?

S: December

T: December 21st is technically the first day of winter, and that's the shortest day of the year. (3.9)

The upper boundary of the ZFI is collaborative sense-making, which involves students constructively "critique[ing], argu[ing] with, and learn[ing] from their peers" (NATIONAL RESEARCH COUNCIL, 2015, p. 30) in response to open-ended questions and tasks. This ZFI recognizes that teachers are typically fluent in posing questions and their facility with questioning can be leveraged in facilitating collaborative sense-making. Students and the teacher can gradually shift from classroom discourse structured around known-answer questions for which the teacher is the mediator of responses to student-centered discussion for which the expectation is to exchange critiques and arguments in the process of collaborative sense-making.

Specifically this ZFI recognizes that through her experience with I-R-E, Mrs. Poppy has developed an affinity for asking about phenomena suitable for collaborative sense-making, as in the following examples:

- "Why does it make sense that when it's 6 a.m. in Florida, that it's not 6 a.m. as well in California" (2.4)?
- "Who gets the day first" (2.9)?
- "Every place on Earth gets the season of winter…Why would they [country abroad] not get the cold and the snow" (3.8)?
- "It snows on top of Mount Kilimanjaro…How does that happen" (3.9)?
- "Do tides happen on [the Great Lakes]" (7.4)?
- "Who can explain why does that [sometimes you see only part of the moon lit up but you can always see the whole moon] happen" (7.5)?
- "So, if the moon is going around Earth all the time, then how come – the sun is shining over here – how come every single time it passes right here, there's not an eclipse" (7.6)?
- "So, why do you think it [tides] might affect the oceans but not lakes and rivers and streams" (8.2)?

These are the types of questions that can initiate generative student exchanges, for as Mercer, Dawes, and Staarman (2009) explain, I-R-E questions, "can be used to provoke pupils' imagination, to explore their wider relevant experience, and to get them to explain their reasoning" (p. 361). Mrs. Poppy's questions are questions that invite students to present arguments.

Moving along the continuum between the lower and upper ZFI boundaries calls for two progressive strategies: establishing classroom discussion norms (Windschitl, 2019) and providing examples for conversation moves (Dawes, 2004; Windschitl, 2019). During I-R-E cycles, students and teachers have very defined roles in which the teacher asks a question and a student or students respond upon permission. This type of organization is the status quo (Colley

& Windschitl, 2016; Windschitl, 2019). Thus, to disrupt the familiar, the first step requires a clear vision for what collaborative sense-making looks like in the classroom. Therefore, Windschitl (2019) suggests the establishment of classroom norms for respecting peers' contributions, intellectual vulnerabilities, and opportunities for participation and for staying on topic. Figure 5.3 from Windschitl's (2019) article "Disciplinary literacy versus doing school," offers examples of constructive classroom norms for discussion.

Figure 5.3
"Our Classroom Talk Norms" (Windschitl, 2019, p. 10)

Our Classroom Talk Norms

Norm	Meaning
Preparation	We will come prepared for discussion by doing the readings and bringing notes, examples, and stories.
Responsible learners	We are responsible for our own learning. This means we speak, request clarification from others, ask others to repeat what they said, or signal agreement or confusion.
Pushing ourselves	We help one another think beyond the obvious, disagree with ideas, and draw out comments from classmates, and we are open to changing our minds.
Focus	Our comments and stories will stay on topic, and we have the right to explain how our contribution connects with the science.
Hearing from all	Everyone has the right to be heard.
Air time	Don't dominate the conversation.
Time to think	The teacher will give think time before asking for our ideas.
Impulse control	Don't interrupt or talk over classmates when they have the floor.
Fair critique	We, the students and teacher, can critique ideas of others, but personal attacks are out of bounds.

Note. The norms are based on ideas presented by Chapin, O'Connor, and Anderson (2012).

Another strategy for approaching the goal of collaborative sense-making is teaching students to use discussion moves to advance the conversation. The teacher can introduce and model the use of sentence starters and questions to probe for more information, indicate active listening, contribute ideas, and elicit contributions from others. Below (Table 5.2) are examples of these discussion moves, organized by purpose.

Table 5.2
Examples of Discussion Moves

Purpose	Example Prompts
Probe for more information	How did you come to that conclusion? Why do you think that? What is your evidence? What do you mean by…?
Indicate active listening	What I hear you saying is… Can you say more about that?
Contribute to an idea by agreeing/disagreeing	I (dis)agree with…but (and want to add)… I (dis)agree with…because… I understand your reasoning, but have you considered…? I would like to add… Building off what…said…
Elicit contributions	Do you agree? …,what do you think? … ,we haven't heard your thoughts about…

The teacher can scaffold students' use of classroom talk norms and sentence stems by modeling the structure of classroom talk. To do this, the teacher poses a question about a scientific phenomenon and asks a student to share her or his thinking. Then, the teacher revoices the student's response using the language from the discussion moves list and asks another student to engage with the previous response. This allows the students practice with deepening a discussion regarding a single concept. Another way to scaffold students' use of classroom norms and sentence stems is to give them a "prediscussion task" (Colley & Windschitl, 2016, p. 1016) in which students write independently or discuss in small groups to prepare for the whole-class discussion.

ZFI: From Think-Alouds to Designing Investigations

Planning investigations is identified by the *Framework* (NATIONAL RESEARCH COUNCIL, 2012) as a significant practice of scientists (p. 50), calling for students to have experiences with planning experimental or observational investigations appropriate for answering well-defined questions or for testing hypotheses by identifying relevant variables, if appropriate; determining how data are to be collected, measured, recorded, and analyzed, and to what degree of precision; and determining how many trials are appropriate, if necessary. In Mrs. Poppy's class, students were not tasked with designing investigations for either of the two units I observed. Thus, the second continuum (see Figure 5.4) aims to help Mrs. Poppy engage students with planning investigations.

Figure 5.4
ZFI for Designing Investigations

At the lower boundary of the continuum is Mrs. Poppy's current practice of thinking aloud, or making her sense-making process audible. Thinking-aloud is a form of modeling (Duke & Pearson, 2002). In the episode described in chapter 4 in which the worksheets did not contain sufficient information for responding to the questions, Mrs. Poppy modeled her strategy for figuring out the correct responses.

> T: Let's see if we can figure it out. It says, *the new moon, the side of the moon facing Earth is dark*. So, then what would the opposite of that be? Where the whole side of the moon facing Earth is light. What's that called? When you can see the whole moon?
>
> Ss: full moon
>
> T: Yup, so that would be this one [T talks aloud as she writes in the answer, "The side of the moon facing Earth is light."] All right, so what do you think about first quarter and third quarter? If this is all dark, and this is all light, what must this one be? What must that one be?

S: half

T: It's half, yup, yup. So, "Half the side of the moon facing Earth is light." So, then, what do you think about third quarter then? It would have to be the same thing except…?

Ss: opposite, other side

T: The opposite half, "The other half of the side of the moon facing Earth is light." See, we don't need their silly information, do we? We can figure it out! (7.6)

By thinking aloud, Mrs. Poppy models the step-by-step process by which she solves problems, a strategy very similar to engaging in a thought experiment. For this reason, I claim that thought experiments lie within Mrs. Poppy's ZFI because they are just beyond her current practice of thinking aloud and because thought experiments are possible without any further provisions from the school.

Thought experiments are mental investigations into phenomena (Metz, 2008; Rogan, 2007) similar to mental training used by athletes. A study by Metz (2008) showed that a collaborative thought experiment effectively guided first grade students through their first experience with investigations. In the thought experiment, students understood the problem presented to them, generated hypotheses and means for testing them, and critiqued ideas concerning the investigation. In a study by Windschitl (2004), teacher candidates who already held Bachelor's degrees in science were tasked with designing their own inquiry investigations. Two teachers, Erica and Amanda, tested the growth of plants planted in various chemical solutions (i.e., bleach and water, floor cleaner, etc.). As they progressed through their investigation, they realized they had not planned thoroughly. For example, they had not identified a control variable nor determined how they would measure the plant growth. When reflecting upon this experience, Amanda suggested that if she were to give students the task of designing investigations, she would begin by posing questions about hypothetical investigations:

> *If I wanted to help my students discover what data is relevant, we could work on some sample problems in class. I could describe an experiment to my students and we could discuss what data answered the question being asked. For instance, if an experiment was designed to answer the question on whether light affects plant growth, does data collected on the soil pH answer the question being asked? This type of activity seems an excellent opportunity for discussion in a group setting*. (Windschitl, 2004, p. 499)

What Amanda described was a thought experiment for plant growth. Amanda sees this cognitive planning as a way for ensuring that all the design elements align with the investigation's purpose. I propose that teacher could extend the use of think alouds to scaffold student engagement in thought experiments. Below I offer an example of thinking aloud about a thought experiment.

> In the winter, I keep pop in the garage rather than taking up room in my refrigerator. Well, last night, I was sitting in the living room when I heard a bunch of explosions. It has been so cold that my pop froze in the can and then burst! But, interestingly, only the diet pop exploded. Why might that be? I think it might be related to the sugar content. How could I test that? If put one can of diet and one can of regular pop in the freezer, would that give me an explanation?

The above thought experiment charges students with developing hypotheses explaining why the pop cans exploded. They must consider their hypotheses to respond to the design question posed by the teacher.

Designing investigations is an important disciplinary practice, but one in which teachers do not often engage students. However, as a hallmark of comprehension instruction, elementary teachers are typically proficient in thinking-aloud. By extending teachers' current use of think-alouds for modeling problem solving (or inferencing) into their ZFI strategy of thought experiments, teachers, even teachers with few material resources, may be able to approximate the *Framework*'s (NATIONAL RESEARCH COUNCIL, 2012) and the MSS's (MDE, 2015) expectation that students plan investigations.

General Conclusions

Since the turn of the century, Michigan has placed high priority on improving reading proficiency scores statewide. The reform efforts targeting this goal have taken penal approaches by attaching student proficiency to school funding and teacher evaluations. In response, schools have taken measures to ensure reading instruction is allotted the most daily instructional time compared to the other academic subject areas (math, science, and social studies) and have placed particular emphasis on the basics of reading–phonemic awareness, phonics, fluency, vocabulary, and comprehension.

In the same time frame, Michigan teachers have been charged with enacting instruction aligned with three different sets of science standards. The standards adopted in 2007, the Grade Level Content Expectations (GLCEs; MDE, 2007) for science present science as a body of knowledge that can be acquired by transmission. The new standards, the Michigan Science Standards (MSS, 2015) call for disciplinary literacy, a stark contrast from the previous expectations.

Mrs. Poppy is a teacher who has been well-prepared to teach science content and English language arts. She is dutiful in meeting the standards for which she is currently responsible. However, her current instructional context is unprepared for supporting a disciplinary literacy approach to science instruction. She does not have materials, curriculum, or even her own educational experiences to rely upon in making these changes.

Mrs. Poppy's current instruction, shaped by the resources and constraints of her context, is characteristic of content-area literacy instruction. This type of instruction neglects the important role of reading, writing, and language in doing science. Nonetheless, there are current practices that can be leveraged in transitioning toward a disciplinary literacy approach. Mrs. Poppy values and seeks students' background knowledge, demonstrates and assesses with visual representations and models, and attends to science vocabulary. These are all worthwhile science activities that can be reconceptualized to align with a disciplinary literacy approach.

The limiting nature of Mrs. Poppy's context presents context-specific challenges for enacting new reforms. Therefore, professional learning opportunities for supporting Mrs. Poppy need to cohere with the limitations and affordances of her context. The National Academies of Sciences, Engineering, and Medicine (2015) recognize the dire need for differentiated professional learning opportunities. A step toward differentiated professional learning is case study research such as this study that immerses those in positions to support teachers in the learning contexts.

I am inspired by the potential for designing zones of feasible innovation for individual teacher learning. As this study has shown, there is a need for context-specific professional learning opportunities; thus, by detailing the creation of zones of feasible innovation for Mrs. Poppy's instruction, I model a process others may choose to emulate in helping teachers approximate the demands of reform-based science.

Recommendations and Implications for Teachers, Curriculum Developers, Professional Development and School Leaders, and Teacher Educators

According to Loeb, Knapp, and Elfers (2008), the development of standards-based reform, such as the NGSS (NGSS Lead States, 2013) or the MSS (MDE, 2015), seems a linear process. First, standards defining what students should learn are created and agreed upon. Then, the standards are connected to an assessment program that is attached to accountability measures. This process, though, they argue is rife with embedded assumptions about what teachers will think and do in response. Loeb et al. (2008) identify those responses as the following assumptions:

> *Assumption One:* Teachers will pay attention to the reform and become familiar with the standards and what they imply for practice (Wilson & Floden, 2001).
>
> *Assumption Two*: Teachers will take the reform seriously, as will their supervisors and other local leaders, who will exhort teachers to meet the demands of the policy, and offer support as needed (Stecher, Chun, Barron, & Ross, 2000).
>
> *Assumption Three*: Teachers will adjust their instruction to align with the standards and associated assessments (including preparation for assessment) (Stecher et al., 2000). In the best sense of the phrase, they will "teach to the test."
>
> *Assumption Four:* Teachers will expect all of their students to succeed–and believe that they are capable of succeeding (Orfield & Kornhaber, 2001). Where students are likely to struggle, teachers will adjust their teaching practice to maximize the students' chances of success (Kannapel, Aagaard, Coe, & Reeves, 2001).
>
> *Assumption Five:* Teachers will have access to appropriate professional learning opportunities (Dutro, Fisk, Koch, Roop, & Wixson, 2002; Thompson & Zeuli, 1999). What is more, those teachers who are not fully prepared to teach to the ambitious learning standards, if not others, will take advantage of these learning opportunities, thereby developing the requisite knowledge, skills, and commitment, and their teaching practice will improve accordingly. (p. 4)

Embedded within these assumptions are additional assumptions about a natural compatibility of instructional contexts with adopted standards. However, the reviews of research in this chapter and chapter two established instructional contexts as dynamic, diverse, and often problematic. Therefore, it is decidedly unreasonable to assume, for instance, that teachers and supervisors who are familiar with the standards know how to translate standards to practice (Assumptions One and Two). Studies by Cohen (1990) and McNeill et al. (2018) indicate the contrary. Both Mrs. O (Cohen, 1990) and the principals (McNeill et al., 2018) understood the standards for which they were charged yet did not have sufficient mathematical knowledge or science expertise, respectively, to connect standards to instructional practice. As an additional example, it is equally unreasonable to assume that teachers who are not "prepared to teach the ambitious learning standards" (Loeb et al., 2008, p. 4) have access to relevant professional learning opportunities. This assumption is misguided. Consider, for instance, that some classrooms are nestled within rural contexts where research-based professional development opportunities of any kind are minimal (Harmon, Gordanier, Henry, & George, 2007). The scarcity is particularly salient in specific content areas, such as science (Kunz, Nugent, Pedersen, DeChenne, & Houston, 2013). Compounding the problem is opportunities farther from home are not feasible for rural teachers either, as money for registrations and substitutes as well as the long travel distances impede rural schoolteachers' attendance, resulting in nationally-collected data that indicate rural teachers have lower professional development participation than teachers in suburban and urban contexts have (Wei, Darling-Hammond, & Adamson, 2010).

Research, such as this study, that inquires of a teacher's instructional context prior to the adoption of the new reform policies allows for examination of the extent to which these assumptions are accurate. While more research examining individual contexts is needed, the findings and conclusions from this study inform recommendations for supporting teachers in making the pedagogical and conceptual changes required of the new science standards and present implications for curriculum developers, professional development and school leaders, and teacher educators.

Supporting Teachers' Enactment of Science Reforms with Educative Curriculum Materials

Content and discourse analyses of the GLCEs (MDE, 2007), the worksheets used during instruction, and course descriptions from Mrs. Poppy's undergraduate courses indicated an explicit focus on science content knowledge. In contrast, the new science standards articulate a disciplinary approach to science education that includes both knowledge and scientific practices. According to Davis (2017), this paradigm shift reestablishes all teachers as novices in this disciplinary approach "because the vision requires sophisticated knowledge and teaching practices not familiar for most teachers" (para. 2). Therefore, pertinent to the success of the standards is assisting teachers in acquiring these knew skills and competencies. One innovative way to support in-service teachers is through the adoption of educative curriculum materials.

Educative curriculum materials are grounded in Remillard's (2005) theory of a participatory relationship between teachers and curriculum materials. Remillard (2005) asserts that teachers "collaborate" (p. 234) with curriculum materials, an interaction that is shaped by the teacher, the materials, and the context. Thus, the content of the curriculum materials plays an integral role in influencing the planned and enacted curriculum (Granger, Bevis, Southerland, Saka, & Ke, 2019; Remillard, 2005).

Educative curriculum materials include traditional materials to support student learning as well as educative features that support teachers' subject area knowledge, pedagogical content knowledge, and pedagogical knowledge (Ball & Cohen, 1996; Bismack, Arias, Davis, & Palincsar, 2014; Davis, 2017). For curriculum materials to be considered "educative," the materials must "make the rationales behind curriculum developers' decisions visible to teachers to help teachers develop flexible knowledge that they can apply to new situations" (McNeill, 2009, p. 238). Davis (2017) lists examples of science-specific educative features:

- unit concept maps and core idea maps
- content storylines (descriptions within each lesson of how the lesson extends the learning from the previous lessons and supports the future learning)
- content boxes that explicate specific disciplinary core ideas within a lesson and how the content ideas are worked on within three-dimensional learning
- features to help teachers recognize why a particular science practice is important in a lesson and giving suggestions for how to support students in engaging in it
- reading and discussion guides
- guides for anticipating students' ideas
- rubrics that show what effective engagement in a science or engineering practice looks like in conjunction with a disciplinary core idea, with sample student work
- narratives that describe how a fictional teacher (based on [Davis, Palincsar, Arias, Bismack, Marulis, & Iwashyna's (2014)] observations in classrooms) adapted a lesson and why she made the choices she did. (para. 5)

Several researchers have explored the potential for educative materials to improve both teaching and learning. In a large, three-year study, Palincsar and colleagues (for brief overview see Davis, Palincsar, Smith, Arias, & Kademian, 2017) conducted a program of research exploring "how educative curriculum materials can support teachers' enactment of science instruction around the science practices, and how this [enactment] influences student learning" (Bismack, Arias, Davis, & Palincsar, 2015, p. 818). The initial study examined how upper elementary teachers use commercially packaged curriculum materials for teaching two units of study, one on electric circuits and one on ecosystems, as written–without educative features but with many opportunities to engage students in scientific practices (Davis, Palincsar, Arias, Bismack, Marulis, & Iwashyna, 2014). Results from this study indicated that the case study teachers provided ample time for students to record scientific observations but offered little time for students to engage in other scientific practices, such as making scientific predictions and constructing evidence-based scientific explanations (Bismack, Arias, Davis, & Palincsar, 2014). Researchers used these results and analyses of the curriculum materials to determine the supports that are most needed to help teachers understand and engage students in scientific practices. The "enhanced" (Davis et al., 2014, p. 45) curriculum materials included the following educative features: supplemental and background content knowledge supports; supports for scientific practices, including overviews, rationales, and reminder boxes; narratives of a fictional teacher's pedagogical decisions in adapting and enacting specific scientific practices; supports for literacy practices to guide the teacher in engaging and advancing text-based discussions; and support for assessment practices, including rubrics and sample student work.

Subsequent studies exploring the potential for these educative curriculum materials found that teachers who attended to the educative features included in the enhanced materials were better able to support students' engagement in science practices. For example, evidence from student work and teacher enactments found that the educative features supported teachers in offering students opportunities to make scientific predictions (Bismack et al., 2015), justifying predictions (Arias, Davis, Marino, Kademian, & Palincsar, 2016; Arias, Smith, Davis, Marino, & Palincsar, 2017), and writing and drawing observations with characteristics of high-quality observations (Bismack et al., 2015). These findings align with other studies that have found positive relationships between teacher and student learning and educative curriculum materials.

In a randomized cluster design study of 125 fourth- and fifth-grade teachers and their students, Granger, Bevis, Southerland, Saka, and Ke (2019) found that teachers in the treatment condition, those provided with educative curriculum materials and brief professional development sessions (approximately 12 hours total), showed increases in science content knowledge, beliefs about reform-based science teaching, and science teaching self-efficacy from pre- to post-study measures. Similarly, Brunner and Abd-El-Khalick (2019) found that educative features added to widely-circulated science trade books contributed to elementary teachers' more informed views on the nature of science and supported teachers in leading effective classroom discussions about science processes.

While educative curriculum materials are promising for assisting in-service teachers, studies on their use have nonetheless found that teachers use the educative features in different ways and to variable extents (Brunner & Abd-El-Khalick, 2019; Davis et al., 2017; Granger et al., 2019; Schneider, Krajcik, & Blumenfeld, 2005) according to their contexts, presenting additional implications for school leaders and teacher educators. For instance, in the initial study, Bismack et al. (2014) found that due to time constraints, teachers often did not complete all parts of the lessons. One of the case study teachers, in particular, Ms. Campbell, did not enact any lesson steps related to the design of investigations or the construction of evidence-based explanations and claims, and she often reduced the number of opportunities students had for engaging in other scientific practices, such as making predictions. When studying Ms. Campbell's enactment of the unit lessons using the educative curriculum materials (Bismack et al., 2015), Ms. Campbell was plagued by similar time constraints and thus, still did not offer students opportunities to write predictions with justifications despite the practice being one focus of the educative features. Further, Ms. Campbell explained that she had many responsibilities at the school, and thus did not have time to comment on students' work.

Similarly, contextual constraints limited the effectiveness of the educative curriculum materials in Schneider, Krajcik, and Blumenfeld's (2005) study. The study explored the extent to which classroom enactments of educative curriculum materials designed to support reform-based science education compared to the intent of the materials. Analyses of observations and materials indicated that two of the case study teachers, Mr. Davis and Ms. Turner, limited students' experiences with technology, small group work, and conversations. Although not presented in the discussion of the results as a possible contributing factor in these findings, the researchers reported in the methods section that these two teachers, unlike the other two teachers in the study, did not have classroom access to computers. Their classes could only use computers when their schools' labs were available. Further complicating the situation, the computer lab at Ms. Turner's school shared a space with the library, potentially contributing to the lack of group work and conversations.

Considered together, these studies (Bismack et al., 2015; Schneider, Krajcik, & Blumenfeld, 2005) suggest that educative curriculum materials and the corresponding professional development are not sufficient for implementing science instruction consistent with the goals of the new science standards. School leaders will need to ensure that school structures allow teachers adequate planning and instructional time for science as well as access to technology and spaces appropriate for science activities. Future research should explore logistical models for school-based scheduling and resource sharing that support science instruction.

Supporting Teachers' Conceptual Change

According to Woodbury and Gess-Newsome (2002), "[W]hat teachers do is greatly influenced by what teachers think" (p. 770). Therefore, also important to this discussion is teachers' thoughts about science. The new science standards challenge traditional conceptions of science; thus, for teachers to enact and maintain reform-based instruction, Gregoire (2003) argues that teachers must commit to "significant changes" (p. 149) in their subject-matter beliefs. Deeply rooted beliefs about science likely contribute to the difficulty teachers–even those with educative curriculum materials–experience with presenting science as both concepts and practice. As mentioned in Bismack et al.'s (2014) initial study, teachers rarely engaged students in evidence-based scientific practices, a tendency that did not change after the implementation of the educative curriculum materials (Arias et al., 2016, p. 1522; Bismack et al., 2015, p. 838). Furthermore, Schneider, Krajcik, and Blumenfeld (2005) found that all of the participating teachers, regardless of their fidelity to the curriculum materials, tended to emphasize ideas, concepts, and accurate answers rather than practices. The teachers participating in these studies seemingly held a conceptualization of science in which the practices could be omitted from scientific work while still maintaining a semblance of science, and neither the educative curriculum materials nor the complementary professional learning opportunities amended those conceptions.

According to many models of conceptual change, changing teachers' long-held understandings and practices requires a level of pedagogical discontentment and self-efficacy (Gregoire, 2003, Southerland, Sowell, Blanchard, & Granger, 2011; Woodbury & Gess-Newsome, 2002). Southerland, Sowell, and Enderle (2011) argue, "Until teachers become discontented with their current understandings of teaching and the results they engender, close consideration of new ideas and practices is unlikely" (p. 454). Therefore, the impetus for change is tension within a teacher's current subject-matter perspectives as a result of pedagogical discontentment, or the uneasiness felt from the realization that the results of one's teaching practices do not meet one's teaching goals (Southerland, Sowell, Blanchard, & Granger, 2011). The second element of conceptual change is self-efficacy, or the confidence a teacher has in her ability to enact instruction that effectively results in student learning. In order to consider ideas of reform-based practices, a teacher must have a positive self-efficacy, that is, she must feel she is capable of successfully implementing new approaches (Gregoire, 2003). Without pedagogical discontentment or sufficient self-efficacy, a teacher is unlikely to attempt new practices.

Based on their research, Southerland, Sowell, Blanchard, and Granger (2011) describe the relationships between pedagogical discontentment and teacher self-efficacy as the intersections of low teaching self-efficacy and high teaching self-efficacy with pedagogical contentment and pedagogical discontentment. They posit that teachers who are pedagogically content are unlikely to take-up reform-based ideas regardless of whether they have high or low teaching self-efficacy. Pedagogically content teachers feel successful with their current practices and either expect those practices to continue to be successful (high teaching self-efficacy) or doubt that they will see as much success with new practices as they do with their current approaches (low teaching self-efficacy). Conversely, teachers who are pedagogically discontented and have low teaching self-efficacy might try reform-based ideas and practices. They are dissatisfied because their current practices do not align with their goals and feel trying reform-based ideas is not any more risky than is continuing with the status quo. On the other hand, teachers who are pedagogically discontented and have high teaching self-efficacy are seeking change and feel confident that they can successfully implement new ideas.

Studies on the effectiveness of educative curriculum materials illuminate these intersectional relationships. For example, in a study exploring the influence of educative curriculum materials and professional development on teacher learning, Granger et al. (2019) found that teachers who indicated high levels of science teaching self-efficacy prior to participation in the interventions learned significantly less from the educative curriculum materials and professional learning opportunities than did teachers who indicated lower science teaching self-efficacy at the onset. Granger et al. (2019) suggested that a possible explanation for this finding was the teachers' lack of pedagogical discontentment.

Although not examined in the discussions of the studies, self-efficacy or pedagogical contentment may have also played a role in teachers' responses to educative curriculum materials in studies by Bismack et al. (2014), Bismack et al. (2015), and Schneider, Krajcik, and Blumenfeld (2005). In these studies Ms. Campbell (Bismack et al., 2014; Bismack et al., 2015), who had previous experience with her grade level science content, and Mr. Davis (Schneider, Krajcik, & Blumenfeld, 2005), who earned a chemistry degree prior to entering the education field, tended to use the educative curriculum materials more sparingly than did the teachers who were less experienced with science knowledge or teaching. Given research by Kahveci, Kahveci, Mansour, and Alarfaj (2018) found an association between high self-efficacy and low levels of intent to reform and a positive correlation between discontentment and high intentions for reform, it is possible that Ms. Campbell and Mr. Davis felt highly self-efficacious or felt content with their current pedagogical goals and outcomes and thus, were less receptive to reforming their practices.

These studies on conceptual change and educative curriculum materials suggest important implications for creators of educative curriculum materials, professional development leaders, and teacher educators. To achieve the conceptual changes required of the paradigm shift in science education standards (MDE, 2015; NGSS Lead States, 2013), professional learning opportunities in the liminal space between reform adoption and reform implementation should focus on pedagogical discontentment and science teaching self-efficacy.

Educative curriculum creators, professional development leaders, and teacher educators should, according to Southerland, Sowell, and Enderle (2011) "capitalize on" or "catalyze" teachers' pedagogical discontentment "by showing teachers a portrait of what is possible in terms of some aspect of their teaching practice and allow them to reflect on their own efforts in this area" (p. 454). This recommendation suggests reflective thinking, a process with robust and enduring support in literature on teacher professional learning (for a review see Šarić and Šteh, 2017), is pertinent to fostering pedagogical discontentment.

Reflective thinking is a "deep and interpretative process that allows for careful judgement" (Slade, Burnham, Catalana, & Waters, 2019, p. 1). Research has shown that reflective thinking leads to pedagogical discontentment by gently problematizing current ideas about, and practices for teaching science (Dam, Janssen, & van Driel, 2018; Danielowich, 2012; Slade et al., 2019; Ward & Haigh, 2017; Yost, Sentner, & Forlenza-Bailey, 2000). Danielowich's (2012) study with pre-service teachers (PSTs) of science highlighted the benefits of engaging PSTs in structured and scaffolded reflective thinking strategies to problematize current conceptions of science teaching. In the study, PSTs designed reform-based lessons and enacted them for their peers or during practicum. Following the enactment, PSTs reflected on discussions and video clips of the lessons and their peers' responses to their lessons, considering the extent to which the aims of their teaching, the structure for learning, and their relationships with students aligned with reform-based practice. Danielowich's (2012) study found that PSTs who used reflections to reveal dissonances between their existing and possible practices were more likely to see those frictions as catalysts for reforming their practice (p. 343). Similarly, Dam, Janssen, and van Driel (2018) found that after a reflection intervention, the strength of teachers' intentions to reform increased and their intentions were more specific than at baseline. Dam et al. (2018) used a "positive approach" (p. 374) to problematizing. The researchers presented nine participating science teachers with lesson segments for a reform-based science curriculum. Then, through the use of a reflective thinking interview, the researchers helped the teachers to identify previous positive experiences with reform-based ideas and to think about how to move that behavior "one step towards" (p. 375) reform-based teaching aligned with the lesson segments, a process akin to developing a zone of feasible innovation (Rogan, 2007) discussed in this chapter.

Dam et al.'s (2018) approach for reforming practice should be explored for its merit in creating pedagogical discontentment as well as for building self-efficacy, the other element in conceptual change. According to Bandura (1997; as cited in Morris, Usher, & Chen, 2017; Usher & Parajes, 2008), one source of teachers' positive teaching self-efficacy is reflection and interpretation of past mastery experiences. Enactive mastery experiences are previous performance attainments achieved through "direct, personal action" (Morris et al., 2017, p. 797) and are "thought to be the most influential source of self-efficacy" (p. 797). In other words, teachers who perceive past experiences with certain practices as successful are more likely to feel confident in enacting similar practices. For example, in a study exploring the influence of multimedia educative curriculum materials on teachers' beliefs about science argumentation, Loper, McNell, Gonzáles-Howard, Marco-Bujosa, & O'Dwyer (2019) found that teachers' self-efficacy increased as they gained experience teaching the lessons. In Dam et al.'s (2018) study, teachers built self-efficacy by considering the strengths of past executions of a practice or idea and "rephrasing" (p. 374) them into solutions.

Thus, to foster pedagogical discontentment and teaching self-efficacy, teachers must have ample opportunities to reflect on their ideas and practices. However, "merely asking teachers to reflect" (Monet & Etkina, 2008, p. 469) is not effective; educative curriculum developers, professional development and school leaders, and teacher educators should provide teachers with explicit and reflective strategies (Ward & Haigh, 2017) for problematizing current ideas about and practices for teaching science and for interpreting past mastery experiences that could be leveraged in meeting reform intentions. Future research should explore the potential of educative curriculum materials designed to help professional development leaders and teacher educators to scaffold teachers through reflective activities that effectively stimulate pedagogical discontentment and build self-efficacy.

Supporting Teachers with Limited Resources

As yet, the recommendations for supporting teachers in enacting science instruction consistent with the pedagogical and conceptual intentions of the new science standards have not addressed supports for teachers like Mrs. Poppy who do not have curriculum materials or access to local professional development opportunities. Research on web-based supports offers suggestions and implications for supporting all teachers, including those with limited resources.

Callahan, Saye, and Brush (2014) engaged in a design-based research study with 13 teachers from diverse school settings to explore the design of a web-based educative curriculum tool, iPlan. The tool provided educative curriculum features for a 4-weeks-long, high school-level, genetic unit, including reminders, rationales, instructional tips, and possible student ideas. iPlan also included a platform for which teachers could enter implementation notes to be shared with other teachers using iPlan or to keep privately as a record of practice. Interview data indicated that all of the participating teachers found some of the educative features helpful in enacting the curriculum. This study suggests the potential for web-based educative curriculum materials but did not study the extent to which teachers used the materials or the effectiveness of the materials in changing teacher practice.

Recently, Loper et al. (2019) took up that line of research, exploring how multimodal educative curriculum materials (MECMs) influenced teachers' beliefs about scientific argumentation and the variation in teachers' use of curriculum materials. The study included 90 middle school teachers from public, private, and charter schools in cities, suburbs, towns, and rural locales from across the United States. All of the teachers in the study received a digital edition of a 62-lesson scientific argumentation curriculum. The digital edition provided to teachers in the intervention group included educative features that offered teachers multimedia representations of practice, such as videos demonstrating scientific argumentation in classrooms, explaining lesson structures, and suggesting pedagogical strategies. The MECMs also included "an active and reflective learning experience through interactive self-assessment prompts that 'pushed' customised video recommendations based on teachers' responses" (p. 177). Researchers collected data from pre- and post-surveys, backend curriculum analytics, and daily self-reports of curriculum use. Analyses indicated that all teachers' self-efficacy beliefs about teaching scientific argumentation increased significantly from pre- to post-survey, and for all teachers the more lessons they taught, the more confident they became in their ability to teach scientific argumentation. Despite the positive gains across the conditions, MECM teachers experienced smaller self-efficacy gains than did teachers in the control group. Looking deeper, researchers found that the more videos MECM teachers watched, the lower their growth. Loper et al. (2019) hypothesize that despite the videos' inclusion of a diverse group students, the videos did not "explicitly discuss diverse students" (p. 188). Thus, while the images of diverse students were present, supports for helping students with diverse educational backgrounds (e.g., English language learners) were not.

Callahan et al.'s (2014) and Loper et al.'s (2019) research highlight teachers' desires to learn from multimedia materials that feature contexts and circumstances similar to their own. Future research should explore web-based educative curriculum materials that offer multimedia and hyperlinked features for adapting lessons and connecting with other teachers according to individual contexts and student needs.

Malanson, Jacque, Faux, and Meiri (2014) explored the potential for such individualized, contextual support by pairing web-based educative curriculum materials with a virtual mentor. The study participants included four teachers, three from Massachusetts and one from Ohio, from very different school contexts. One Massachusetts teacher from an urban college-preparatory high school served as the control. This teacher participated in "gold standard" in-person, graduate-level professional development and received asynchronous educative curriculum materials including narratives for supporting the facilitation of classroom discussions, explanations of the critical components of learning objectives, and emphases on the NGSS (NGSS Lead States, 2013) three-dimensional learning. The other three teachers (one from an urban Massachusetts high school with a high population of English-language learners; one from a suburban Massachusetts public high school, and one from a regional high school in Ohio) received a combination of asynchronous and synchronous virtual supports. Synchronous virtual support included a virtual mentor who met with the teachers individually over a period of two months. The virtual mentor and the teachers worked on building content knowledge, identifying science misconceptions, identifying potential student questions, and implementing pedagogies and strategies appropriate for each teacher’s context. Teachers also participated in real-time reflections. Synchronous virtual support included web-based educative curriculum materials akin to those of the control teacher’s but with the addition of videos, a discussion forum, and a news blog. Data were collected from pre- and post-measures of student content understanding and problem solving reflected in the NGSS’ three dimensions, and student self-efficacy. Analyses indicated that students in all participating schools demonstrated large and significant gains on all measures regardless of teacher condition. These results suggest that a combination of virtual mentoring and web-based educative curriculum materials are as effective as in-person professional development relevant to educative materials. Furthermore, these findings suggest that virtual mentorships provide teachers in diverse contexts and remote locations with personalized, effective professional development that leads to reform-based instruction and student achievement. Future research should expand research on virtual mentorships and educative curriculum materials to explore options for making these supports available through open-access platforms.

Michigan’s new science standards represent a paradigm shift in science education. Findings from this study demonstrate that the current resources informing teachers’ instruction are insufficient for meeting the pedagogical and conceptual changes required of the new standards. Educative curriculum materials in tandem with corresponding professional development have the potential to support teachers in enacting instruction congruent with the new standards, but more research is needed for how these materials and professional development leaders can effectively problematize and leverage individual teachers' current instructional practices. Currently educative curriculum materials and professional development are not equitably available for all educators. Future research must continue to explore web-based, open access educative curriculum materials and professional learning opportunities. Measures such as these will support teachers and students in achieving the vision set forth by the Michigan Science Standards.

APPENDICES

APPENDIX A

Three Dimensional Framework

Three Dimensions of the Next Generation Science Standards (NGSS Lead States, 2013)		
Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Asking questions & defining problems • Planning & carrying out investigations • Analyzing & interpreting data • Developing and using models • Constructing explanations and designing solutions • Engaging in argument from evidence • Using mathematics & computational thinking • Obtaining, evaluating, & communicating information	Physical Science PS1: Matter & its interactions PS2: Motion & stability: Forces & interactions PS3: Energy PS4: Waves & applications Life Science LS1: From molecules to organisms LS2: Ecosystems: Interactions, energy, & dynamics LS3: Heredity: Inheritance & variation of traits LS4: Biological evolution: Unity & diversity Earth & Space Science ESS1: Earth's place in the universe ESS2: Earth's systems ESS3: Earth & human activity Engineering, Technology, & Applications of Science ETS1: Engineering design ETS2: Links among engineering, technology, science, & society	• Patterns • Cause & effect: Mechanism & prediction • Scale, proportion, & quality • Systems and system models • Energy & matter: Flows, cycles, & conservation • Structure & function • Stability & change

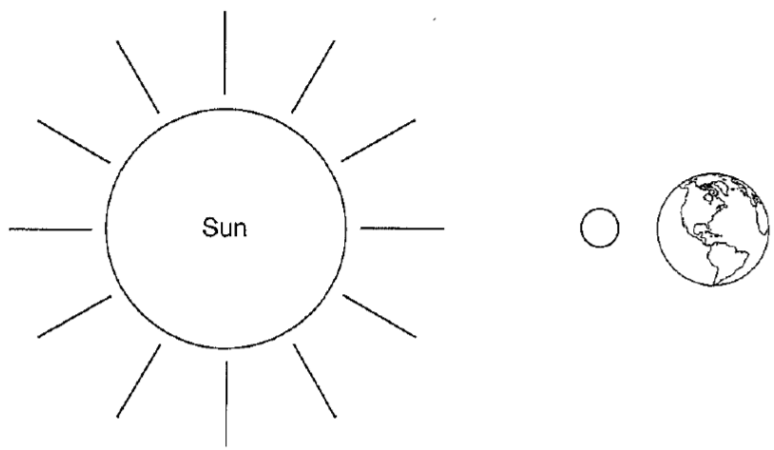
APPENDIX B

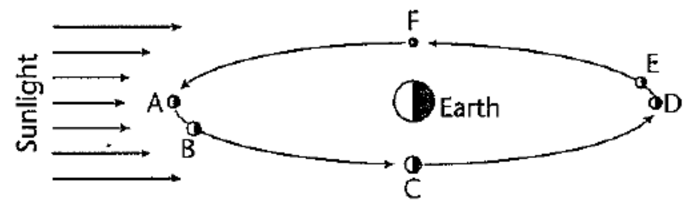
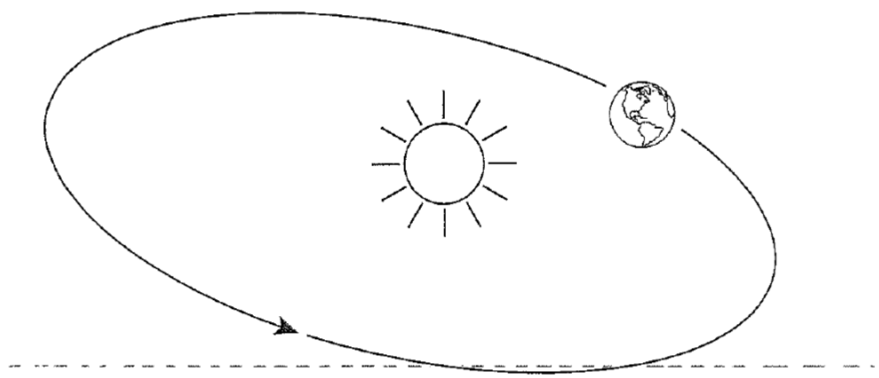
Interview Protocol

Demographics	How many years have you been teaching? How many years have you been teaching science at this level?
Curriculum	How do you determine what to teach in science? Does your district have a curriculum? a scope and sequence? Do you use a commercial curriculum program? What are the science units at your grade level? What constitutes a unit? Which unit will you teach during my observations?
Goals/Texts	What are your goals for science instruction? How do you match curriculum to those goals? What do scientists do that you hope students take away from your science instruction? What is the role of investigations in science? What is the role of texts in science?
Unit Planning	How do you begin to plan for a science unit? How do you choose activities? texts? assignments? How do you motivate or interest students in the unit? What information do students need to know before starting the unit? How do you model scientific practices? How do students learn content? How do you ask students to demonstrate their understanding of content?

APPENDIX C

Worksheet Task by Type

Task	Example
Add to a diagram (AD)	**5.** The drawing below shows the sun, the moon, and Earth during a solar eclipse. Draw lines from the moon to Earth that show the shadow. 

Answer questions regarding a diagram (DQ)	**Understanding Main Ideas** *Use the following figure to answer questions 1 and 2. Write your answers on a separate sheet of paper.* **1.** What phases of the moon would someone on Earth see when the moon is at positions A through F? **2.** What kind of tide (spring or neap) will occur when the moon is at positions A, C, D, and F? 
Label a diagram (LD)	**2.** The picture shows Earth's revolution around the sun. Label Earth and the sun. 

Match vocabulary words with definitions (MV)	**3.** Draw a line from each term to its meaning. **Term** / **Meaning** axis — **a.** the movement of one object around another object rotation — **b.** the imaginary line that passes through Earth's center and the North and South poles revolution — **c.** the spinning of Earth
Define vocabulary words (DV)	**Building Vocabulary** *Write a brief description of each of the following.* **5.** force ______________________________ ______________________________

<table>
<tr>
<td>Fill in the blanks with words from a word bank
(WB)</td>
<td>

7. Read each word in the box. In each sentence below, fill in the correct word or words.

solar eclipse	lunar eclipse	umbra

a. Earth comes directly between the moon and the sun in a(an) ____________________.

b. In a(an) ____________________, the moon's shadow hits Earth.

</td>
</tr>
<tr>
<td>Complete a table
(CT)</td>
<td>
<table>
<tr><th colspan="3">Seasons in the Northern Hemisphere</th></tr>
<tr><th>Season</th><th>Length of Daytime</th><th>How the Northern Hemisphere Tilts</th></tr>
<tr><td>Summer</td><td>longer than night</td><td>b. toward the sun</td></tr>
<tr><td>Winter</td><td>a. Shorter than night</td><td>away from the sun</td></tr>
</table>
</td>
</tr>
</table>

Fill in the blanks (no word bank) (FB)	*Answer the following questions. Use your textbook and the ideas above.* **1.** The inner planets are called the _____________________ planets.
Circle the correct response – one correct response (CR)	**2.** Circle the letter of how many inner planets there are. **a.** 2 **b.** 4 **c.** 6
Circle the correct responses (MR)	**13.** Circle the letter of each sentence that is true about Neptune. **a.** Neptune's largest moon is called Triton. **b.** Scientists think that Neptune is shrinking. **c.** Neptune is much larger than Uranus.
Answer true or false (TF)	**3.** Is the following sentence true or false? Most of Earth's surface is covered with water. __________

Write a short answer (SA)	**Understanding Main Ideas** *Answer the following questions in the spaces provided.* 1. How are gravity and weight related? ________________ ________________ ________________

APPENDIX D

Worksheet Tasks by Item, Coded According to Revised Version of Bloom's Taxonomy (Krathwohl, 2002)

Worksheet	Participation Structure	Question Type	Question Taxonomy
Earth in Space ARS	Whole group	AD	B2
		LD	A1
		MV	A1
		MR	B2
		WB	A1
		CT	B2
Earth in Space SS	Whole group		
Earth in Space RR	Independent	SA* (x2)	B2
		DQ*(x3)	B2
		MV* (x8)	A1
Gravity & Motion ARS	Whole group	WB	A1
		MR	B2
		TF	A1
		WB	A1
		AD	B2
Gravity & Motion SS	Whole group		
Gravity & Motion RR	Independent	SA* (x5)	B2

Worksheet	Participation Structure	Question Type	Question Taxonomy
		DV* (x5)	A1
Phases, Eclipses, & Tides ARS	Whole group	MR	B2
		FB	A1
		CT	B2
		FB	A1
		AD	B2
		TF	B1
		WB	A1
		TF	B1
		WB	A1
		MR	B2
P, E, & T SS	Whole group		
P, E, & T RR	Independent	SA* (x3)	B2
		DQ	B2
		DQ	B2
		WB* (x10)	A1
The Sun ARS	Whole group	FB	B1
		CR	B1
		CT w/ WB	A1
		MV	A1
		TF	B1
		CR	B2
		WB	A1
		FB	B2
The Sun SS	Whole group		
The Sun RR	Independent	LD* (x6)	B1

Worksheet	Participation Structure	Question Type	Question Taxonomy
		MV* (x11)	A1
		SA* (x3)	B2
The Inner Planets ARS	Independent	FB	A1
		CR	A1
		TF	B2
		LD w/ WB	B1
		MR	B2
		LD	A1
		MR	B2
		FB	B2
		TF	A1
		MR	A2
		TF	A1
		CR	A1
The Outer Planets ARS	Independent	CR	B1
		FB	A1
		AD	B1
		MR	B2
		TF	A1
		CR	A1
		TF	A1
		LD	A1
		MR	B2
		MR	B2
		TF	A1
		TF	A1

Worksheet	Participation Structure	Question Type	Question Taxonomy
		MR	B2
		TF	A1
		FB	B2
The Inner Planets SS The Outer Planets SS	Whole group		
The Inner Planets RR	Independently	SA* (x2)	B2
		LD* (x4)	A1
		FB* (x10)	B2
The Outer Planets RR	Independently	SA* (x6)	B2
Comets, Asteroids and Meteors ARS	Whole group	WB	A1
		TF	B1
		FB	A1
		CR	B1
		TF	B2
		MR	B2
		TF	B1
		CT w/ WB	A1

APPENDIX E

Solar System GLCE Alignment Chart

Earth Systems Standard	Worksheet Section in which Standard is Addressed	Standard Addressed in Lesson	Assessment Item Aligned with Standard
E.ES.M.6 Seasons- Seasons result from annual variations in the intensity of sunlight and length of day due to the tilt of the Earth on its axis, and revolution around the sun.	Section 1: "Earth in Space"	"It deals with the title and which part is pointing at the sun" (3.4). "So even though it's summer for me in Michigan, it's also summer in Florida, but they're going to have a warmer summer because they have more direct light" (3.6).	Item 1: Multiple choice response to *The seasons of the Earth are caused by:* Item 30: Short answer response to *Explain and describe how seasons on Earth happen.*
E.ES.05.61 Demonstrate using a model, seasons as a result of variations in the intensity of sunlight caused by the tilt of the Earth on its axis, and revolution around the sun.	Section 1: "Earth in Space"	Model demonstration in observation 3. "When the Northern Hemisphere is tipped and pointing toward the sun, the Northern Hemisphere is having summer" (3.2).	
E.ES.05.62 Explain how the revolution of the Earth around the sun defines a year.	Section 1: "Earth in Space"	"*Revolution is the movement of one object around another. The path that Earth follows around the sun is called an orbit. Earth takes*	Item 2: Multiple choice response to *One year on Earth is a certain length because:*

Earth Systems Standard	**Worksheet Section in which Standard is Addressed**	**Standard Addressed in Lesson**	**Assessment Item Aligned with Standard**
		one year to travel all the way around the sun in its orbit. So that's what causes one year for us is when the Earth goes around the sun one time" (3.1)	
E.ST.M.1 Solar System – The sun is the central and largest body in our solar system. Earth is the third largest planet from the sun in a system that includes other planets and their moons, as well as smaller objects, such as asteroids and comets.	Section 4: "The Sun" Section 5: "The Inner Planets" Section 6: "The Outer Planets" Section 7: "Comets, Asteroids, and Meteors"	"You will need to know the difference between all of these, like between a comet, an asteroid, meteor, meteorite, meteoroid" (12.4).	Item 4: Multiple choice response to *Which of the following puts the celestial objects in the correct order, from largest to smallest:*
E.ST.05.11 Design a model that describes the position and relationship of the planets and other objects (comets and asteroids) to the sun.	Section 4: "The Sun" Section 5: "The Inner Planets" Section 6: "The Outer Planets" Section 7: "Comets, Asteroids, and Meteors"	"We're going to do a mnemonic device for the plants in order from the sun outward" (11.2). "*Most asteroids revolve around the sun between the orbits of Mars and Jupiter"* (12.4).	Item 3: Multiple choice response to *Which of the following puts the celestial objects in the correct order, from closest to the sun to farthest away from the sun:* Item 27: Labeling response to *Number the planets in order from closest to the sun (1) to farthest away from the sun (8)*
E.ST.M.2 Solar System Motion - Gravity is the force that keeps most objects in the solar system in regular and predictable motion.	Section 2: "Gravity in Motion"	"*Two factors – inertia and gravity-combine to keep Earth in orbit around the sun and the moon in orbit around Earth*" (6.2). "Everything has gravitational attraction to everything else in our universe" (8.2).	Item 5: Multiple choice response to *Gravity is responsible for which of the following:*

Earth Systems Standard	Worksheet Section in which Standard is Addressed	Standard Addressed in Lesson	Assessment Item Aligned with Standard
E.ST.05.21 Describe the motion of planets and moons in terms of rotation on axis and orbits due to gravity.	Section 2: "Gravity in Motion"	"*Two factors – inertia and gravity-combine to keep Earth in orbit around the sun and the moon in orbit around Earth*" (6.2).	
E.ST.05.22 Explain moon phases as they relate to the position of the moon in its orbit around the Earth, resulting in the amount of observable reflected light.	Section 3: "Phases, Eclipses, and Tides"	"*The phase of the moon you see depends on how much of the sunlit side of the moon faces Earth…The moon reflects light from the sun"* (7.5). "new moon, *the side of the moon facing Earth is dark"* (7.6).	Item 6: Multiple choice response to *We sometimes see the moon as a crescent because* Item 27: Response to diagram *Which letter is the position of the moon during the new moon phase?*
E.ST.05.23 Recognize that nighttime objects (stars and constellations) and the sun appear to move because the Earth rotates on its axis and orbits the sun.	Section 1: "Earth in Space"	"Our key concept for this section, *Earth through space in two major ways: rotation and revolution"* (1.3). "*Earth's rotation causes day and night. As Earth rotates from east to west, the sun appears to move across the sky. The sun is not really moving. Earth's rotation makes it appear to move*" (1.6). "It looks like the sun is getting bigger, right? But it's not that the sun is getting bigger. We're turning on Earth and are able to see more of the sun (1.8).	Item 7: Multiple choice response to *Throughout the day the sun moves across the sky, and throughout the night the stars move across the sky due to* Item 26: Response to diagram *At which letter on Earth would a person be experiencing nighttime?*
E.ST.05.24 Explain lunar and solar eclipses based on the relative positions of the Earth, moon, and sun, and the orbit of the moon.	Section 3: "Phases, Eclipses, and Tides"	"*A solar eclipse occurs when the moon passes directly between Earth and the sun, blocking sunlight from Earth"* (7.6).	Item 8: Multiple choice response to *A lunar eclipse is when* Item 9: Multiple choice response to *A solar eclipse is when*

Earth Systems Standard	**Worksheet Section in which Standard is Addressed**	**Standard Addressed in Lesson**	**Assessment Item Aligned with Standard**
		"Flip it to the back and draw me a lunar eclipse…Can you please include the shadow if you haven't already" (8.1)? "Can you please copy down that solar eclipse and then draw the shadow" (8.1)?	Item 28: Response to diagram *At which letter of the moon's position would it be possible for a total lunar eclipse to occur?* Item 29: Diagram and description task *Draw a diagram below in each appropriate box, showing both types of eclipse* [solar eclipse and lunar eclipse]. *Please include labels. Give a description of each.*
E.ST.05.25 Explain the tides of the oceans as they relate to the gravitational pull and orbit of the moon.	Section 3: "Phases, Eclipses, and Tides"	"*Tides are caused mainly by differences in how much the moon's gravity pulls on different parts of the Earth"* (8.2).	Item 10: Multiple choice response to *Ocean tides are caused by*

REFERENCES

Allen, C., & Penuel, W. R. (2015). Studying teachers' sensemaking to investigate teachers' responses to professional development focused on new standards. *Journal of Teacher Education, 66*(2), 136-149. doi:10.1177/0022487114560646

Altieri, J.L. (2016). *Reading science: Practical strategies for integrating instruction.* Portsmouth, NH: Heinemann.

American Association for the Advancement of Science. (1990). *Science for all Americans: Project 2061.* New York, NY: Oxford University Press.

Anderson, L.W., Krathwohl, D.R., Airasian, P.W., Cruikshank, K.A., Mayer, R.E., Pintrich, P.R., Raths, J., & Wittrock, M.C. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York, NY: Addison Wesley Longman, Inc.

Arias, A.M., Davis, E.A., Marino, J-C., Kademian, S.M., & Palincsar, A.S. (2016). Teachers' use of educative curriculum materials to engage students in science practices. *International Journal of Science Education, 38*(9), 1504-1526. doi:10.1080/09500693.2016.1198059

Arias, A.M., Smith, P.S., Davis, E.A., Marino, J-C., & Palincsar, A.S. (2017). Justifying predictions: Connecting use of educative curriculum materials to students' engagement in science argumentation. *Journal of Science Teacher Education, 28*(1), 11-35. doi:10.1080/1046560X.2016.1277597

Ball, D.L. (1996). Teacher learning and the mathematics reforms: What we think we know and what we need to learn. *The Phi Delta Kappan, 77*(7), 500-508.

Ball, D.L., & Cohen, D.K. (1996). Reform by the book: What is: Or might be: The role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6-8, 14. doi:10.2307/1177151

Banilower, E.R., Smith, P.S., Malzahn, K.A., Plumley, C.L., Gordon, E.M., & Hayes, M.L. (2018). *Report of the 2018 NSSME+.* Chapel Hill, NC: Horizon Research Inc.

Barber, J. (2019). All-text science or no-text science. In M.C. Cruz and N.K. Duke (Eds.). *No more science kits or texts in isolation,* (pp. 1-10). Portsmouth, NH: Heinemann.

Beck, I.L., McKeown, M.G., & Kucan, L. (2013). *Bringing words to life: Robust vocabulary instruction* (2nd ed.). New York, NY: The Guilford Press.

Birman, B.F., Desimone, L., Porter, A.C., & Garet, M.S. (2000). Designing professional development that works. *Educational Leadership, 57*(8), 28-33.

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

Bismack, A.S., Arias, A.M., Davis, E.A., & Palincsar, A.S. (2015). Examining student work for evidence of teacher uptake of educative curriculum materials. *Journal of Research in Science Teaching, 52*(6), 816-846. doi:10.1002/tea.21220

Blachowicz, C. (2014). What we know about vocabulary acquisition and what it means for instruction. In N. K. Duke & E. O. Keene (Eds.), *No more "look up the list" vocabulary instruction* (pp. 17-41). Portsmouth, NH: Heinemann.

Bloome, D., Carter, S.P., Christian, B.M., Otto, S., & Shuart-Faris, N. (2005). *Discourse analysis & the study of classroom language and literacy events–A microethnographic perspective.* Retrieved from Amazon.com

Brezicha, K., Bergmark, U., & Mitra, D.L. (2015). One size does not fit all: Differentiating leadership to support teachers in school reform. *Educational Administration Quarterly, 51*(1), 96-132. doi:10.1177/0013161X14521632

Brunner, J.L., & Abd-El-Khalick, F. (2029). Improving nature of science instruction in elementary classes with modified science trade books and educative curriculum materials. *Journal of Research in Science Teaching, 57*(2), 154-183. doi:10.1002/tea.21588

Busch, C., De Maret, P.S., Flynn, T., Kellum, R., Le, S., Meyers, B., Saunders, M., White, R., & Palmquist, M. (1994-2012). Content analysis. Writing@CSU. Colorado State University. https://writing.colostate.edu/guides/guide.cfm?guideid=61

Callahan, C., Saye, J., & Brush, T. (2014). Social studies teachers' interactions with second generation web-based educative curriculum. *The Journal of Social Studies Research, 38*(3), 129-141. doi:10.1016/jssr.2014.03.002

Campsen, L. (2013). *Scheduling challenges: Tiered reading intervention*. rtinetwork.org

Cervetti, G. N., & Barber, J. (2009). Text in hands-on science. In E.H. Hiebert & M. Sailors (Eds.), *Finding the right texts: What works for beginning and struggling readers* (pp. 88-108). New York, NY: Guilford Press.

Cervetti, G.N., & Pearson, P.D. (2012). Reading, writing, and thinking like a scientist. *Journal of Adolescent & Adult Literacy, 55*(7), 580-586. doi:10.1002/JAAL.00069

Cervetti, G.N., DiPardo, A.L., & Staley, S.J. (2014). Entering the conversation: Exploratory talk in middle school science. *The Elementary School Journal, 114*(4), 547-572. doi:10.1086/675638

Cervetti, G.N., Hiebert, E.H., Pearson, P.D., & McClung, N.A. (2015). Factors that influence the difficulty of science words. *Journal of Literacy Research, 47*(2), 1-33. doi:10.1177/1086296X15615363

Charalambous, C.Y., Hill, H.C., & Mitchell, R.N. (2012). Two negatives don't always make a positive: Exploring how limitations in teacher knowledge and the curriculum contribute to instructional quality. *Journal of Curriculum Studies, 44*(4), 489-513. doi:10.1080/00220272.2012.716974

Chard, D.J. (2004). Toward a science of professional development in early reading instruction. *Exceptionality, 12*(3), 175-191. doi:10.1207/s15327035ex1203_5

Chauvin, R., & Theodore, K. (2015). Teaching content-area literacy and disciplinary literacy. *SEDL Insights, 3*(1), 1-10. Austin, TX: SEDL.

Cohen, D.K. (1990). A revolution in one classroom: The case of Mrs. Oublier. *Educational Evaluation and Policy Analysis, 12*(3), 311-329. doi:10.3102/01623737012003311

Cohen, D.K. (2011).*Teaching and its predicaments.* Cambridge, MA: Harvard University Press.

Cohen, D.K., Raudenbush, S.W., & Ball, D.L. (2003). Resources, instruction, and research. *Educational Evaluation and Policy Analysis, 25*(2), 119-142. doi:10.3102/01623737025002119

Colley, C., & Windschitl, M. (2016). Rigor in elementary science students' discourse: The role of responsiveness and supportive conditions for talk. *Science Education, 100*(6), 1009-1038. doi:10.1002/sce.21243

Concannon-Gibney, T., & McCarthy, M.J. (2012). The explicit teaching of reading comprehension in science class: A pilot professional development program. *Improving Schools, 15*(1), 73-88. doi:10.1177/1365480211433726

Coté, N., Goldman, S.R., & Saul, E.U. (1998). Students making sense of informational text: Relations between processing and representation. *Discourse Processes, 25*(1), 1-53. doi:10.1080/01638539809545019

CrazyScienceLady. (2015). The scientific method [PowerPoint slides]. Retrieved from https://www.teacherspayteachers.com/Store/Crazysciencelady

Creswell, J.W. (2013). *Qualitative inquiry & research design* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Cuban, L. (2013). Why so many structural changes in schools and so little reform in teaching practice? *Journal of Educational Administration, 51*(2), 109-125. doi:10.1108/09578231311304661

Dam, M., Janssen, F.J.J.M., & van Driel, J.H. (2018). Attention to intentions: How to stimulate strong intentions to change. *Research in Science Education, 48*(2), 369-387. doi:10.1007/s11165-016-9572-4

Danielowich, R.M. (2012). Looking through different lenses: How preservice science teachers use practice-oriented reflections to negotiate more reform-minded identities. *Journal of Science Teacher Education, 23*(4), 323-346. doi:10.1007/s10972-012-9273-4

Daniels, H., Zemelman, S., & Steineke, N. (2007). *Content area writing: Every teacher's guide.* Portsmouth, NH: Heinemann.

Darling-Hammond, L. (2006). *Powerful teacher education: Lessons from exemplary programs.* San Francisco, CA: Jossey-Bass.

Darling-Hammond, L., Hyler, M.E., & Gardner, M. (2017). *Effective teacher professional development.* Palo Alto, CA: Learning Policy Institute.

Davis, E.A. (2017, June). *Educative curriculum materials and the Next Generation Science standards* [Workshop paper]. Instructional Materials for the Next Generation Science Standards: Design, Selection, and Implementation, Washington, D. C. https://sites.nationalacademies.org/DBASSE/BOSE/DBASSE_180249

Davis, E.A., Palincsar, A.S., Arias, A.M., Bismack, A.S., Marulis, L.M., & Iwashyna, S.K. (2014). Designing educative curriculum materials: A theoretically and empirically driven process. *Harvard Educational Review, 84*(1), 24-52. doi:10.17763/haer.84.1.g48488u230616264

Davis, E.A., Palincsar, A.S., Smith, P.S., Arias, A.M., & Kademian, S.M. (2017). Educative curriculum materials: Uptake, impact, and implications for research and design. *Educational Researcher, 46*(6), 293-304. doi:10.3102/0013189X17727502

Dawes, L. (2004). Research report: Talk and learning in classroom science. *International Journal of Science Education, 26*(6), 677-695. doi:10.1080/0950069032000097424

Desimone, L.M. (2011). A primer on effective professional development. *Kappan Magazine, 92*(6), 68-71.

Desimone, L.M., Porter, A.C., Garet, M.S., Yoon, K.S., & Birman, B.F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis*, *24*(2), 81-112.

Dickinson, V.L., & Young, T.A. (1998). Elementary science and language arts: Should we blur the boundaries? *School Science and Mathematics*, *98*(6), 334-339. doi:10.1111/j.1949-8594.1998.tb17429.x

Duke, N.K., & Pearson, P.D. (2002). Effective practices for developing reading comprehension. In A. E. Farstrup & S. J. Samuels (Eds.), *What research has to say about reading instruction* (3rd ed., pp. 205-242). Newark, DE: International Reading Association.

Durkin, D. (1978-1979). What classroom observations reveal about reading comprehension instruction. *Reading Research Quarterly, 14*(4), 481-533. doi:10.1598/RRQ.14.4.2

Eunice Kennedy Shriver National Institute of Child Health and Human Development. (2000). Report of the National Reading Panel: Teaching children to read: Reports of the subgroups (00-4752). Washington, DC: U.S. Government Printing Office.

Fang, Z. (2005). Scientific inquiry: A systemic functional linguistics perspective. *Science Education*, *89*(2), 335-347. doi:10.1002/sce20050

Fang, Z., & Coatum, S. (2013). Disciplinary literacy: What you need to know about it. *Journal of Adolescent and Adult Literacy*, *56*(8), 627-632. doi:10.1002/JAAL.190

Fenstermacher, G.D., & Richardson, V. (2005). On making determinations of quality teaching. *Teachers College Record, 107*(1), 186-213. doi:10.1111/j.1467-9620.2005.00462.x

Fisher, D., Brozo, W.G., Frey, N., & Ivey, G. (2011). *50 instructional routines to develop content literacy* (2nd ed.). Boston, MA: Pearson Education, Inc.

Freire, P. (1998). *Pedagogy of freedom: Ethics, democracy, and civic courage* (P. Clarke, Trans.). Lanham, MD: Rowman & Littlefield Publishers, Inc.

Frye, E.M., Trathen, W., & Schlagal, B. (2010). Extending acrostic poetry into content learning: A scaffolding framework. *The Reading Teacher, 63*(7), 591-595. doi:10.1598/RT.63.7.6

Galus, P.J. (2003). A testable prediction. *The Science Teacher*, *70*(5), 10.

Gee, J.P. (2001). Reading as situated language: A sociocognitive perspective. *Journal of Adolescent & Adult Literacy*, *44*(8), 714-725. doi:10.1598/JAAL.44.8.3

Gee, J.P. (2004). Reading as situated language: A sociocognitive perspective. In D.E. Alvermann, N. Unraue, & R. B. Ruddell (Eds.), *Theoretical models and processes of reading* (116-132). Newark, DE: International Reading Association.

Gee, J.P. (2015). *Social linguistics and literacies* (5th ed.). New York, NY: Routledge.

Glen, N.J., & Dotger, S. (2013). Writing like a scientist: Exploring elementary teachers' understandings and practices of writing in science. *Journal of Science Teacher Education, 24*(6), 957-976. doi:10.1007/s10972-013-9348-x

Granger, E.M., Bevis, T.H., Southerland, S.A., Saka, Y., Ke, F. (2019). Examining features of how professional development and enactment of curricula influences elementary science teacher learning. *Journal of Research in Science Teaching*, *56*(3), 348-370. doi:10.1002/tea.21480

Gregoire, M. (2003). Is it a challenge or a threat? A dual-process model of teachers' cognition and appraisal processes during conceptual change. *Educational Psychology Review, 15*(2), 147-179. doi:10.1023/A:1023477131081

Grierson, A.L., & Woloshyn, V.E. (2013). Walking the talk: Supporting teachers' growth with differentiated professional learning. *Professional Development in Education, 39*(3), 401-419. doi:10.1080/19415257.2012.763143

Halliday, M.A.K. (1994). *An introduction to functional grammar* (2nd ed.). London: Edward Arnold.

Hand, B.M., Alvermann, D.E., Gee, J., Guzzetti, B.J., Norris, S.P., Philips, L.M., Parin, V., & Yore, L.D. (2003). Message from the "Island Group": What is literacy in science literacy? *Journal of Research in Science Teaching, 40*(7), 607-615. doi:10.1002/tea.10101

Harmon, H.L., Gordanier, J., Henry, L., & George, A. (2007). Changing teaching practices in rural schools. *Rural Educator, 28*(2), 8-12.

Hiebert, E.H., & Cervetti, G.N. (2012). What difference in narrative and informational texts mean for the learning and instruction of vocabulary. In J. Baumann & E. Kame'enui (Eds.), *Vocabulary instruction: Research to Practice* (2nd ed., pp. 322-344). New York, NY: The Guilford Press.

Hill, H.C. (2009). Fixing teacher professional development. *The Phi Delta Kappan, 90*(7), 470-476.

Hill, H.C., Beisiegel, M., & Jacob, R. (2013). Professional development research: Consensus, crossroads, and challenges. *Educational Researcher, 42*(9), 476-487. doi:10.3102/0013189X13512674

Houseal, A., Gillis, V., Helmsing, M., & Hutchison, L. (2016). Disciplinary literacy through the lens of the next generation science standards. *Journal of Adolescent & Adult Literacy, 59*(4), 377-384. doi:10.1002/jaal.497

Ingvarson, L., Meiers, M., & Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practice, student outcomes & efficacy. *Education Policy Analysis Archives, 13*(10), 1-28. Retrieved from http://epaa.asu.edu/epaa/v13n10

Judson, E., Ernzen, J., Krause, S., Middleton, J.A., & Culbertson, R.J. (2016). How engineering standards are interpreted and translated for middle school. *Journal of Pre-College Engineering Education Research, 6*(1), 1-10. doi:10.7771/2157-9288.1121

Jung, E., Brown, E.T., & Karp, K.S. (2014). Role of teacher characteristics and school resources in early mathematics learning. *Learning Environment Research, 17,* 209-228. doi:10.1007/210984-014-9159-9

Kahveci, A., Kahveci, M., Mansour, N., & Alarfaj, M.M. (2018). Exploring science teachers' affective states: Pedagogical discontentment, self-efficacy, intentions to reform, and their relationships. *Research in Science Education, 48*(6), 1359-1386. doi:10.1007/s11165-016-9606-y

Kennedy, M. (2005). *Inside teaching: How classroom life undermines reform.* Cambridge, MA: Harvard University Press.

Kennedy, M.M. (2016). How does professional development improve teaching? *Review of Educational Research, 86*(4), 945-980. doi:10.3102/0034654315626800

Korthagen, F. (2017). Inconvenient truths about teacher learning: Towards professional development 3.0. *Teachers and Teaching, 23*(4), 387-405. doi:10.1080/13540602.2016.1211523

Kraft, M.A., & Blazar, D. (2018). Taking teacher coaching to scale: Can personalized training become standard practice? *Education Next, 18*(4), 69-74.

Krajcik, J.S., & Sutherland, L. M. (2010). Supporting students in developing literacy in science. *Science, 328*(5977), 456-459. doi:10.1126/science.1182593

Krathwohl, D.R. (2002). A revision of Bloom's Taxonomy: An overview. *Theory Into Practice, 41*(4), 212-218. doi:10.1207/s15430421tip4104_2

Kunz, G.M., Nugent, G.C., Pedersen, J., DeChenne, S.E., & Houston, J. (2013, November). Meeting rural science teachers' needs: Professional development with on-going technology-delivered instructional coaching. Roundtable at the annual meeting of American Educational Research Association, San Francisco, CA.

Laing, S.P. & Kamhi, A.G. (2002). The use of think-aloud protocols to compare inferencing abilities in average- and below-average readers. *Journal of Learning Disabilities, 35*(5), 437-448. doi:10.1177/00222194020350050401

Lipson, M.Y. (1983). The influence of religious affiliation on children's memory for text information. *Reading Research Quarterly, 18*(4), 448-457.

Loeb, H., Knapp, M.S., & Elfers, A.M. (2008). Teachers' response to standards-based reforms: Probing reform assumptions in Washington State. *Education Policy Analysis Archives, 16*(8), Retrieved from http://epaa.asu.edu/epaa/v16n8/.

Loeb, H., Knapp, M.S., & Elfers, A.M. (2008). Teachers' response to standards-based reform: Probing reform assumptions in Washington State. *Education Policy Analysis Archives, 16*(8). Retrieved from http://epaa.asu.edu/epaa/v16n8

Loper, S., McNeill, K.L., González-Howard, M., Marco-Bujosa, L.M., & O'Dwyer, L.M. (2019). The impact of multimedia educative curriculum materials (MECMs) on teachers' beliefs about scientific argumentation. *Technology, Pedagogy, and Education*, *28*(2), 173-190. doi:10.1080/1475939X.2019.1583121

Malanson, K., Jacque, B., Faux, R., & Meiri, K.F. (2014). Modeling for fidelity: Virtual mentorship by scientists fosters teacher self-efficacy and promotes implementation of novel high school biomedical curricula. *PLoS ONE, 9*(12), e114929. doi:10.1371/journal.pone.0114929

Martin, J.R. (2000). Beyond exchange: Appraisal systems in English. In S. Hunston & G. Thompson (Eds.), *Evaluation in text: Authorial stance and the construction of discourse* (pp. 142-175). Oxford: Oxford University Press.

Martin, J.R., & Rose, D. (2003). *Working with discourse: Meaning beyond the clause*. London: Continuum.

Masuda, A.M., Ebersole, M.M., & Barrett, D. (2013). A qualitative inquiry: Teachers' attitudes and willingness to engage in professional development experiences at different career stages. *The Delta Kappa Gamma Bulletin, 79*(2), 6-14..

McCarthey, S.J. (2001). Identity construction in elementary readers and writers. *Reading Research Quarterly, 36*(2), 122-151.

McMurrer, J. (2007). *Choices, changes, and challenges: Curriculum and instruction in the NCLB era.* Washington, DC: Center on Education Policy.

McNeill, K.L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education, 93*(2), 233-268. doi:10.1002/sce.20294

McNeill, K.L., Lowenhaupt, R.J., & Katsch-Singer, R. (2018). Instructional leadership in the era of the NGSS: Principals' understandings of science practices. *Science Education, 102*, 452-473. doi:10.1002/sce.21336

McTighe, J., & Wiggins, G.P. (2013). *Essential questions: Opening doors to student understanding.* Alexandria, VA: ASCD

Mercer, N., Dawes, L., & Staarman, J.K. (2009). Dialogic teaching in the primary science classroom. *Language and Education, 23*(4), 353-369. doi:10.1080/09500780902954273

Merriam, S.B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

Metz, K.E. (2008). Narrowing the gulf between the practices of science and the elementary school science classroom. *The Elementary School Journal, 109*(2), 138-161. doi:10.1086/590523

Michigan Assessment Consortium (2018). *A recent history of educator evaluation policy in Michigan*. Mason, MI: Michigan Assessment Consortium.

Michigan Department of Education. (2007). Science grade level content expectations. Lansing, MI: Authors.

Michigan Department of Education. (2015). Michigan science standards. Lansing, MI: Authors.

Michigan Department of Education. (2017). *Michigan action plan for literacy excellence.* Lansing, MI: Author.

Mills, J., Birks, M., & Hoare, K. (2014). Grounded theory. In J. Mills and M. Birks (Eds.), *Qualitative methodology: A practical guide* (pp. 107-121). Thousand Oaks, CA: Sage Publications.

Moje, E.B. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. *Journal of Adolescent & Adult Literacy 52*(2), 96-107. doi:10.1598/JAAL.52.2.1

Monet, J.A., & Etkina, E. (2008). Fostering self-reflection and meaningful learning: Earth science professional development for middle school science teachers. *Journal of Science Teacher Education*, *19*(5), 455-475. doi:10.1007/s10972-008-9106-7

Moore, D.W., Readence, J.E., & Rickelman, R.J. (1983). An historical explanation of content area reading instruction. *Reading Research Quarterly*, *18*(4), 419-438. doi:10.2307/747377

Morris, D.B., Usher, E.L., & Chen, J.A. (2017). Reconceptualizing the sources of teaching self-efficacy: A critical review of emerging literature. *Educational Psychology Review*, *29*(4), 795-833. doi:10.1007/s10648-016-9378-y

Moss, B. (2005). Making a case and a place for effective content area literacy instruction in the elementary grades. *The Reading Teacher*, *59*(1), 46-55. doi:10.1598/RT.59.1.5

National Academies of Sciences, Engineering, and Medicine. (2015). *Science teachers learning: Enhancing opportunities, creating supportive contexts.* Committee on Strengthening Science Education through a Teacher Learning Continuum. Board on Science Education and Teacher Advisory Council, Division of Behavioral and Social Science and Education. Washington, DC: The National Academies Press.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common core state standards for English language arts*. Washington, DC: Authors.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press. doi:10.17226/13165

National Research Council. (2015). *Guide to implementing the next generation science standards.* Committee on Guidance on Implementing the Next Generation Science Standards. Board of Education, Division of Behavioral and Social Sciences and Education. Washington, D.C.: The National Academies Press.

Newkirk, T. (1996). Seduction and betrayal in qualitative research. In P. Mortensen & G.E. Kirsch (Eds.), *Ethics and representation in qualitative studies of literacy* (pp. 3-16). Urbana, IL: National Council of Teachers of English.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

No Child Left Behind Act of 2001, P.L. 107-110, 20 U.S.C. § 1111 (2002).

Nystrand, M., & Gamoran, A. (1991). Instructional discourse, student engagement, and literature achievement. *Research in the Teaching of English, 25*(3), 261-290.

Palincsar, A.S. (2013). The *Next Generation Science Standards* and the *Common Core State Standards*: Proposing a happy marriage. *Science and Children, 51*(1), 10-15. doi:10.2505/4/sc13_051_01_10

Parsons, S.A., Hutchison, A.C., Hall, L.A., Parsons, A.W., Ives., S.T., Leggett, A.B. (2019). U.S. teachers' perceptions of online professional development. *Teacher and teacher education,* 82, 33-42. doi:10.1016.j.tate.2019.03.006

Payne, C.M. (2008). *So much reform so little change: The persistence of failure in urban schools.* Cambridge, MA: Harvard University Press.

Remillard, J.T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*(2), 211-246. doi:10.3102/00346543075002211

Remillard, J.T., & Bryans, M.B. (2004). Teachers' orientations about the relationship among curriculum materials: Implications for teacher learning. *Journal for Research in Mathematics Education, 35*(5), 352-388.

Remillard, J.T., & Heck, D.J. (2014). Conceptualizing the curriculum enactment process in mathematics education. *ZDM Mathematics Education, 46*, 705-718. doi:10.1007/s11858-014-0600-4

Rogan, J.M. (2007). How much curriculum change is appropriate? Defining a zone of feasible innovation. *Science Education Policy, 91*(3), 439-460. doi:10.1002/sce.20192

Rose, D. (2012). Genre in the Sydney school. In J. P. Gee & M. Handford (Eds.), *The Routledge handbook of discourse analysis* (pp. 209-225). London: Routledge.

Roychoudhury, A., & Rice, D. (2010). Discourse of making sense of data: Implications for elementary teachers' science education. *Journal of Science Teacher Education, 21*(2), 181-203. doi:10.1007/s10972-009-9165-4

Ruiz-Primo, M.A., & Furtak, E. (2007). Exploring teachers' informal formative assessment practices and students' understanding in the context of scientific inquiry. *Journal of Research in Science Teaching, 44*(1), 57-84. doi: 10.1002/tea.20163

Šarić, M., & Šteh, B. (2017). Critical reflection in the professional development of teachers: Challenges and possibilities. *Center for Educational Policy Studies Journal, 7*(3), 67-85.

Schellings, G., Aarnoutse, C., & van Leeuwe, J. (2006). Third-grader's think-aloud protocols: Types of reading activities in reading an expository text. *Learning and Instruction, 16*, 549-568. doi:10.1016/j.learninstruc.2006.10.004

Schleppegrell, M.J. (2004). *The language of schooling: A functional linguistics perspective.* New York, NY: Routledge.

Schleppegrell, M.J. (2012). Systemic Functional Linguistics. In J.P. Gee & M. Handford (Eds.), *The Routledge Handbook of Discourse Analysis* (pp. 21-34). London: Routledge.

Schneider, R.M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching, 42*(3), 283-312. doi:10.1002/tea.20055

Senn, G.J., McMurtie, D.H., & Coleman, B.K. (2013). RAFTing with raptors: Connecting science, English language arts, and the Common Core State Standards, *Middle School Journal, 44*(3), 52-55. doi:10.1080/00940771.2013.11461855

Shanahan, C., & Shanahan, T. (2014). Does disciplinary literacy have a place in elementary school? *The Reading Teacher, 67*(8), 636-639. doi:10.1002/trtr.1257

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Educational Review, 78*(1), 40-59. doi:10.17763/haer.78.1.v62444321P602101

Shanahan, T., & Shanahan, C. (2012). What is disciplinary literacy and why does it matter? *Top Language Disorders, 32*(1), 7-18. doi:10.1097/TLD.0b013e318244557a

Shulman, L.S. (1992). Research on teaching: A historical and personal perspective. In F.K. Oser, A. Dick, & J-L. Patry (Eds.), *Effective and responsible teaching: The new synthesis* (pp. 14-34). San Francisco, CA: Jossey-Bass Publishers.

Slade, M.L., Burnham, T.J., Catalana, S.M., & Waters, T. (2019). The impact of reflective practice on teacher candidates' learning. *International Journal for the Scholarship of Teaching and Learning, 13*(2), 1-10. doi:10.20429/ijsotl.2019.130215

Southerland, S.A., Sowell, S., & Enderle, P. (2011). Science teachers' pedagogical discontentment: Its sources and potential for change. *Journal of Science Teacher Education, 22*(5), 437-457. doi:10.1007/s10972-011-9242-3

Southerland, S.A., Sowell, S., Blanchard, M., & Granger, E.M. (2011). Exploring the construct of pedagogical discontentment: A tool to understand science teachers' openness to reform. *Research in Science Education, 41*(3), 299-317. doi:10.1007/s11165-010-9166-5

Spradley, J.P. (2009). *Participant observation.* Long Grove, IL: Waveland Press, Inc.

Swales, J.M., & Malczewski, B. (2001). Discourse management and new-episode flags in MICASE. In R. C. Simpson & J. M. Swales (Eds.), *InCorpus linguistics in North America: Selections from the 1999 Symposium* (pp. 145-164). Ann Arbor, MI: The University of Michigan Press.

Taylor, B.M. (1979). Good and poor readers' recall of familiar and unfamiliar text. *Journal of Reading Behavior*, *11*(4), 375-380.

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). *Teacher professional learning and development: Best evidence synthesis iteration (BES)*. Auckland, New Zealand: University of Auckland.

Tovani, C. (2004). *Do I really have to teach reading? Content, comprehension, grades 6-12.* Portland, ME: Stenhouse Publishers.

Tracey, D.H., & Morrow, L.M. (2012). *Lenses on reading: An introduction to theories and models* (2nd ed.). New York, NY: The Guilford Press.

Usher, E.L., & Parajes, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of Educational Research, 78*(4), 751-796. doi:10.3102/0034654308321456

Vo, T. Forbes, C.T., Zangori, I., & Schwarz, C.V. (2015). Fostering third-grade students' use of scientific models with the water cycle: Elementary teachers' conceptions and practices. *International Journal of Science Education, 37*(15), 2411-2432. doi:10.1080/09500693.2015.1080880

von de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: A decade of research. *Educational Psychology Review, 22*(3), 271-296. doi:10.1007/S10648-010-9127-6

Vygotsky, L.S. (1978). *Mind in society: The development of higher mental process.* Cambridge, MA: Harvard University Press.

Ward, G., & Haigh, M. (2017). Challenges and changes: Developing teachers' and initial teacher education students' understandings of the nature of science. *Research in Science Education, 47*(6), 1233-1254. doi:10.1007/s11165-016-9543-9

Wei, R.C., Darling-Hammond, L., & Adamson, F. (2010). *Professional development in the*

United States: Trends and challenges. Dallas, TX: National Staff Development Council.

Windschitl, M. (2004). Folk theories of "inquiry:" How preservice teachers reproduce the discourse and practices of an atheoretical scientific method. *Journal of Research in Science Teaching, 41*(5), 481-512. doi:10.1002/tea.200010

Windschitl, M. (2019). Disciplinary literacy versus doing school. *Journal of Adolescent & Adult Literacy, 63*(1), 7-13. doi:10.1002/jaal.964

Woodbury, S., & Gess-Newsome, J. (2002). Overcoming the paradox of change without difference: A model of change in the arena of fundamental school reform. *Educational Policy, 16*(5), 763-782. doi:10.1177/089590402237312

Yin, R.K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage Publications, Inc.

Yore, L.D., Florence, M.K., Pearson, T.W., & Weaver, A.J. (2006). Written discourse in scientific communities: A conversation with two scientists about their views of science, use of language, role of writing in doing science, and compatibility between their epistemic views of language. *International Journal of Science Education, 28*(2-3), 109-141. doi:10.1080/09500690500336601

Yost, D.S., Sentner, S.M., & Forlenza-Bailey, A. (2000). An examination of the construct of critical reflection: Implications for teacher education programming in the 21st century. *Journal of Teacher Education, 51*(1), 39-49. doi:10.1177/002248710005100105